

**BIOMECHANICAL ANALYSIS OF SELECTED JUDO TECHNIQUES:  
INTERPRETATIONS ON KINEMATIC VARIABLES IN ACCORDANCE  
WITH COMPETITION WEIGHT CATEGORIES**

A Thesis  
submitted to the University of Calicut through the  
Department of Physical Education  
for the fulfillment of the requirement for the  
**DOCTOR OF PHILOSOPHY IN PHYSICAL EDUCATION**

*By*  
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**December 2023**

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## **DECLARATION**

I hereby declare that the work presented in the thesis entitled **“Biomechanical Analysis of Selected Judo Techniques: Interpretations on Kinematic Variables in Accordance with Competition Weight Categories”** is based on the original work done by me under the guidance of **Dr. Sakeer Hussain V.P**, Director, Department of Physical Education, University of Calicut and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

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## **CERTIFICATE**

This is to certify that the thesis entitled “**Biomechanical Analysis of Selected Judo Techniques: Interpretations on Kinematic Variables in Accordance with Competition Weight Categories**” submitted to the University of Calicut, in fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Physical Education is recorded of original research work done by **Rajkiran A.K**, during the period of 2016 – 2023 of his study in the Department of Physical Education, University of Calicut, Thenhipalam, under my supervision and guidance and the thesis has not been previously submitted elsewhere for the award of any Degree/Diploma/Associate ship/Fellowship or any other similar title and it represents entirely an independent work on the part of the candidate.

The examiners have not recommended any modifications or suggestions and therefore the original thesis is resubmitted as such. Soft copy attached is the same as that of the resubmitted copy.

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Dedicated to

Dr. B.R. Ambedkar & Prof. Jigaro Kano

## **Acknowledgement**

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- ❖ Effects of Judo Specific Complex Training Program on selected Motor Components among intercollegiate Level judokas, *International journal of Yogic, Human Movement and Sports Sciences*, ISSN-2456-4419, volume 4, 2019.
- ❖ Effects movement education program on selected psychomotor abilities among elementary level students, *POSEIDON, Journal of commerce, management and social sciences. Vol.6 Dec.17* ISSN 2319-6238, 2017.
- ❖ A Study on the Application of Musculoskeletal Modeling for Selected Physical Activities, NRSM 15, *Inter Disciplinary Research review*, ISBN 9788193167076, 2015.

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# TABLE OF CONTENTS

	Page No.
List of Tables	
List of Figures	
List of Appendices	
<b>I. INTRODUCTION .....</b>	<b>1 - 48</b>
Rationale of the Study .....	1
Sports and Sports Biomechanics.....	2
Kinematic Properties .....	7
Elucidation of Judo.....	11
Principles of Judo .....	21
Aims of Judo .....	22
Fundamentals of Judo.....	24
Conceptual Framework of Judo Technique.....	28
Biomechanics of Judo.....	37
Statement of the Problem .....	41
Objectives of the Study.....	42
Delimitations of the Study .....	42
Limitations of the Study.....	43
Hypotheses of the Study.....	44
Definitions and Explanations of the Related Terms .....	45
Significance of the Study.....	48
<b>II. REVIEW OF THE RELATED LITERATURE.....</b>	<b>49 - 80</b>
Studies on Application of Biomechanical Analysis in Judo .....	49
Studies on Biomechanical Analysis of Combat Sports .....	64
Studies on Biomechanics in the Field of Sports.....	69
<b>III. METHODS AND PROCEDURE .....</b>	<b>81 - 106</b>
Selection of Participants.....	81
Selection of Variables .....	82
Conceptual clarification in the throwing dynamics and static actions of selected judo techniques .....	87
Selection of Experiment Equipment.....	101
Reliability of Data.....	103

	Motion Capture Protocol.....	103
	Collection of Data .....	106
	Statistics.....	106
	Level of Significance.....	107
	Research Design.....	108
<b>IV.</b>	<b>ANALYSIS OF DATA AND THE RESULTS OF THE STUDY.....</b>	<b>109 - 212</b>
	Analysis of Data .....	110
	Analysis of Kinematic Variables .....	112
	Findings of the Study .....	186
	Discussion of Findings.....	204
	Discussion of the Hypotheses.....	208
<b>V.</b>	<b>SUMMARY AND CONCLUSIONS.....</b>	<b>213 - 219</b>
	Summary .....	213
	Conclusions.....	215
<b>VI.</b>	<b>RECOMMENDATIONS .....</b>	<b>221 - 223</b>
	Recommendations .....	221
	<b>BIBLIOGRAPHY.....</b>	<b>i - vii</b>
	Books and Manuals.....	i
	Journals and Periodicals.....	ii
	Electronic and Web References .....	vii
	<b>APPENDICES .....</b>	<b>i - ix</b>

## List of Tables

Table	Title	Page No.
1	Selected Dependent Variables	82
2	Selected Judo Techniques	86
3	Selected Weight Categories	101
4	Abbreviations of selected Kinematic Variables	110
5	Abbreviations of selected Independent Variables	110
6	Classification of Competition Weight Categories	111
7	Descriptives of the Kinematic Variables in accordance with weight categories	114
8	Box's Test of Equality of Covariance Matrices	116
9	Two- way Multivariate Analysis of kinematic variables in accordance with weight categories corresponding to the selected judo techniques	117
10	Tukey's Post Hoc test for Kinematic Variables in accordance with weight categories	118
11	Descriptives of kinematic variables corresponding to the classification of Judo Techniques accordance with the weight categories	122
12	Box's Test of Equality of Covariance Matrices	126
13	Two- way Multivariate Analysis (MANOVA) of kinematic variables in accordance with weight categories corresponding to the Tachi Waza classification of selected Judo Techniques	127
14	Tukey's Post Hoc test for Kinematic Variables in accordance with Weight categories corresponding to the Tachi Waza classification of judo Techniques.	128
15	Tukey's Post Hoc test for Kinematic Variables in accordance with Tachi Waza classification of Judo Techniques	132

Table	Title	Page No.
16	Descriptive of Angular Velocity in accordance with weight categories among selected Judo Techniques	142
17	ANOVA of the Kinematical Variable Angular Velocity in accordance with weight categories corresponding to selected Judo Techniques	144
18	Tukey's Post Hoc test for Angular Velocity in accordance with weight categories corresponding to Selected judo techniques	145
19	Descriptive of Angular Displacement in accordance with weight categories among selected Judo Techniques	149
20	ANOVA of the Kinematical Variable Angular Displacement in accordance with weight categories corresponding to selected Judo Techniques	151
21	Tukey's Post Hoc test for Angular Displacement in accordance with weight categories corresponding to Selected judo techniques	152
22	Descriptive of Movement Time in accordance with weight categories among selected Judo Techniques	157
23	ANOVA of the Kinematical Variable Movement Time in accordance with weight categories corresponding to selected Judo Techniques	159
24	Tukey's Post Hoc test for Movement Time in accordance with weight categories corresponding to Selected judo techniques	160
25	Descriptive of Height of Center of Gravity (CoG) in accordance with weight categories among selected Judo Techniques	164
26	ANOVA of the Kinematical Variable Height of Center of Gravity (CoG) in accordance with weight categories corresponding to selected Judo Techniques	166
27	Tukey's Post Hoc test for Height of Center of Gravity (CoG) in accordance with weight categories corresponding to Selected judo techniques	167
28	Descriptives of Angle of Hip Flexion in accordance with weight categories among selected Judo Techniques	171
29	ANOVA of the Kinematical Variable Angle of Hip Flexion in accordance with weight categories corresponding to selected Judo Techniques	173

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Table	Title	Page No.
30	Tukey's Post Hoc test for Angle of Hip Flexion in accordance with weight categories corresponding to Selected judo techniques	174
31	Descriptives of Angle of knee flexion in accordance with weight categories among selected Judo Techniques	179
32	ANOVA of the Kinematical Variable Angle of knee flexion in accordance with weight categories corresponding to selected Judo Techniques	181
33	Tukey's Post Hoc test for Angle of Knee Flexion Displacement in accordance with weight categories corresponding to Selected judo techniques	182

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## List of Figures

Figure	Title	Page No.
1	Application of mechanical principles to athletic performance	5
2	Cartesian 2D coordinate system for positioning	9
3	Cartesian 3D coordinate system for positioning	9
4	Angular Motion expressed as radians	10
5	Judo Class: Prof. Jigaro Kano teaching uki goshi	17
6	Eishoji Temple, the birthplace of Kodokan Judo	18
7	Kodokan is the International University for Judo	20
8	Kano Jigaro: Shihan & Founder of Kodokan Judo	20
9	The Traditional Dojo	24
10	Bio-mechanics of Judo	38
11	Determination of Angular Displacement	83
12	Determination of Height of CoG	84
13	Determination of Angle of Hip Flexion	85
14	Determination of Angle of knee flexion	85
15	Kumikata variations in Sizentai (Normal Posture) and Jigo tai (Defensive posture)	87
16	Kuzushi Offbalancing	88
17	Kuzhushi (Method of off balancing)	89
18	Tsukuri (Body fitting/Positioning)	90
19	Tai Sabaki (foot movements while positioning of Body)	91
20	Kake (Execution of Technique)	91
21	Execution of Ippon-Seoi-Nage (One Arm Shoulder Throw)	92
22	Execution of Seoi-Otoshi (Kneeling shoulder drop)	93

Figure	Title	Page No.
23	Execution of Tai-Otoshi (Body Drop)	94
24	Execution of O-Goshi (Major Hip Throw)	95
25	Execution of Harai-Goshi (Sweeping Hip Throw)	96
26	Execution of Koshi-Guruma (Hip Wheel)	97
27	Execution of O-Soto-Gari (Major Outer Reap)	98
28	Execution of Uchi-Mata (Inner Thigh Throw)	99
29	Execution of O-Uchi-Gari (Major Inner Reap)	100
30	Video Camera I	102
31	Video Camera II	102
32	Video Capture Set Up as per Rules and Regulations of IJF (International Judo Federation)	104
33	Landmark Placements	105
34	Mean precedence of Angular Velocity corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	135
35	Mean precedence of Angular Displacement corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	136
36	Mean precedence of Movement Time corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	137
37	Mean precedence of Height of Center of Gravity corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	138
38	Mean precedence of Angle Hip Joint corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	139
39	Mean precedence of Angle of knee flexion corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories	140
40	Mean Comparison of Angular Velocity corresponding to the selected Judo Techniques	144

Figure	Title	Page No.
41	Mean Comparison of Angular Displacement corresponding to the selected Judo Techniques	151
42	Mean Comparison of Movement time corresponding to the selected Judo Techniques	158
43	Mean Comparison of Height of Center of Gravity corresponding to the selected Judo Techniques	166
44	Estimated Marginal Means of Angle of Hip Flexion	173
45	Mean Comparison of Angle of knee flexion corresponding to the selected Judo Techniques	180

## QR Code System

In this research report the researcher employed QR Code as a tool for enriching the exploration and comprehension of various topics pertaining to Judo. As you navigate through the following pages, the researcher encourages you to scan the QR Codes provided to unlock a richer understanding of the concepts explained withing this report.

Each code represents an opportunity to delve deeper into Judo, transcending traditional boundaries of learning and embracing the possibilities afforded by technology.

### List of QR Codes

Sl. No.	Title	Page No.
1	Elucidation of Judo	11
2	Conceptual Framework of Judo Techniques	28
3	Phases of Judo Techniques	87

# **Biomechanical Analysis of Selected Judo Techniques: Interpretations on Kinematic Variables in Accordance with Competition Weight Categories**

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## **ABSTRACT**

This research study was engrossed on biomechanical analysis of judo techniques, aims to provide a comprehensive understanding of the kinematic properties and its interactions involved in the execution of judo techniques with respect to the competition weight categories. By rigorously analysing the selected techniques using motion capture technology and biomechanical principles, the researcher seeks to contribute to the development of evidence-based training methods and competition strategies in the field of judo. To determine the influence of weight categories on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships. The objectives were as to investigate the differences in kinematics among the judo techniques chosen with respect to the weight categories in the All-India Interuniversity level judo championships, to quantify the kinematic properties of the judo techniques chosen and to compare specified kinematical characteristics between various weight categories. To meet the objectives three research hypothesis formulated was there is a significant interaction between Weight Categories and Judo Techniques on Kinematic Variables in the execution of selected judo techniques at All-India Interuniversity level judo championships. MANOVA was used as the statistical tool and the result shows that there is a significant interaction between competition weight categories and selected judo techniques with Pillai's trace F value 19.302 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the hypothesis Between Groups were accepted. With this study the researcher contributes to the growing body of knowledge in judo biomechanics by revealing significant differences in kinematic variables across competition weight categories and selected techniques. By elucidating these nuances, we aim to facilitate informed coaching practices, refine training methodologies, and ultimately elevate the performance standards within the sport of judo.

**Keywords:** Biomechanics, Kinematics, Judo, Tachi Waza

# Biomechanical Analysis of Selected Judo Techniques: Interpretations on Kinematic Variables in Accordance with Competition Weight Categories

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## സംഗ്രഹം

ഈ ഗവേഷണ പഠനം ജൂഡോ ടെക്നിക്കുകളുടെ ബയോമെക്കാനിക്കൽ വിശകലനത്തിൽ മുഴുകിയിരിക്കുന്നു, മത്സര ഭാര വിഭാഗങ്ങളുമായി ബന്ധപ്പെട്ട് ജൂഡോ ടെക്നിക്കുകളുടെ നിർവ്വഹണത്തിൽ ഉൾപ്പെട്ടിരിക്കുന്ന ചലനാത്മക സവിശേഷതകളെയും അതിന്റെ ഇടപെടലുകളെയും കുറിച്ച് സമഗ്രമായ ഒരു ധാരണ നൽകാൻ ലക്ഷ്യമിടുന്നു. മോഷൻ ക്യാപ്ചർ സാങ്കേതികവിദ്യയും ബയോമെക്കാനിക്കൽ തത്വങ്ങളും ഉപയോഗിച്ച് തിരഞ്ഞെടുത്ത സാങ്കേതിക വിദ്യകൾ കർശനമായി വിശകലനം ചെയ്യുന്നതിലൂടെ, ജൂഡോ മേഖലയിലെ തെളിവുകൾ അടിസ്ഥാനമാക്കിയുള്ള പരിശീലന രീതികളും മത്സര തന്ത്രങ്ങളും വികസിപ്പിക്കുന്നതിന് ഗവേഷകൻ ശ്രമിക്കുന്നു. ഓൾ-ഇന്ത്യ ഇന്റർയൂണിവേഴ്സിറ്റി ലെവൽ ജൂഡോ ചാമ്പ്യൻഷിപ്പുകളിൽ തിരഞ്ഞെടുത്ത ജൂഡോ ടെക്നിക്കുകളുടെ നിർവ്വഹണവുമായി ബന്ധപ്പെട്ട് കിനിമാറ്റിക് വേരിയബിളുകളിൽ ഭാരം വിഭാഗങ്ങളുടെ സ്വാധീനം നിർണ്ണയിക്കാൻ. അവിഭേദിത അന്തർസർവകലാശാല തല ജൂഡോ ചാമ്പ്യൻഷിപ്പിൽ വെയ്റ്റ് വിഭാഗങ്ങളുമായി ബന്ധപ്പെട്ട് തിരഞ്ഞെടുത്ത ജൂഡോ ടെക്നിക്കുകൾക്കിടയിലെ ചലനാത്മകതയിലെ വ്യത്യാസങ്ങൾ അന്വേഷിക്കുക, തിരഞ്ഞെടുത്ത ജൂഡോ ടെക്നിക്കുകളുടെ ചലനാത്മക സവിശേഷതകൾ അളക്കുക, വിവിധ ഭാരം തമ്മിലുള്ള നിർദ്ദിഷ്ട ചലനാത്മക സവിശേഷതകൾ താരതമ്യം ചെയ്യുക എന്നിവയായിരുന്നു ലക്ഷ്യങ്ങൾ. വിഭാഗങ്ങൾ. ഓൾ-ഇന്ത്യ ഇന്റർയൂണിവേഴ്സിറ്റി ലെവൽ ജൂഡോ ചാമ്പ്യൻഷിപ്പുകളിൽ തിരഞ്ഞെടുത്ത ജൂഡോ ടെക്നിക്കുകളുടെ നിർവ്വഹണത്തിൽ ഭാര വിഭാഗങ്ങളും ജൂഡോ ടെക്നിക്കുകളും തമ്മിൽ ചലനാത്മക വേരിയബിളുകൾ തമ്മിൽ കാര്യമായ ഇടപെടൽ നടക്കുന്നുണ്ടെന്ന് ലക്ഷ്യങ്ങൾ നിറവേറ്റുന്നതിനായി മൂന്ന് ഗവേഷണ സിദ്ധാന്തങ്ങൾ രൂപീകരിച്ചു. MANOVA സ്ഥിതിവിവരക്കണക്ക് ഉപകരണമായി ഉപയോഗിച്ചു, ഫലം കാണിക്കുന്നത് മത്സര ഭാര വിഭാഗങ്ങളും തിരഞ്ഞെടുത്ത ജൂഡോ ടെക്നിക്കുകളും തമ്മിൽ പിള്ളയുടെ ടേസ് എഫ് മൂല്യമായ 19.302-മായി 0.05 ലെവലിൽ p മൂല്യം (0.001<0.05) മുതൽ പ്രാധാന്യമുള്ളതാണ്. അതിനാൽ, ഗ്രൂപ്പുകൾ തമ്മിലുള്ള സിദ്ധാന്തം അംഗീകരിക്കപ്പെട്ടു. ഈ പഠനത്തിലൂടെ, മത്സര ഭാര വിഭാഗങ്ങളിലും തിരഞ്ഞെടുത്ത സാങ്കേതികതകളിലുമുള്ള

ചലനാത്മക വേരിയബിളുകളിൽ കാര്യമായ വ്യത്യാസങ്ങൾ വെളിപ്പെടുത്തിക്കൊണ്ട് ജൂഡോ ബയോമെക്കാനിക്സിലെ വർദ്ധിച്ചുവരുന്ന അറിവിലേക്ക് ഗവേഷകൻ സംഭാവന ചെയ്യുന്നു. ഈ സൂക്ഷ്മതകൾ വ്യക്തമാക്കുന്നതിലൂടെ, അറിവോടെയുള്ള പരിശീലന രീതികൾ സുഗമമാക്കാനും പരിശീലന രീതികൾ പരിഷ്കരിക്കാനും ജൂഡോ കായികരംഗത്ത് ആത്യന്തികമായി പ്രകടന നിലവാരം ഉയർത്താനും ഞങ്ങൾ ലക്ഷ്യമിടുന്നു.

**കീവേഡുകൾ:** ബയോമെക്കാനിക്സ്, കിനിമാറ്റിക്സ്, ജൂഡോ, ജൂഡോ ടെക്നിക്കുകൾ, കോംബാറ്റ് സ്റ്റോർട്സ്

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# Chapter I

## **INTRODUCTION**

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Rationale of the Study.....	1
Sports and Sports Biomechanics .....	2
Kinematic Properties .....	7
Elucidation of Judo.....	11
Principles of Judo.....	21
Aims of Judo.....	22
Fundamentals of Judo .....	24
Conceptual Framework of Judo Technique .....	28
Biomechanics of Judo .....	37
Statement of the Problem.....	41
Objectives of the Study .....	42
Delimitations of the Study.....	42
Limitations of the Study .....	43
Hypotheses of the Study .....	44
Definitions and Explanations of the Related Terms.....	45
Significance of the Study.....	48

The advancement of sports sciences has long been contingent upon a nuanced comprehension of sports Biomechanics, as it serves as a cornerstone in elucidating the analysis on performance of athletes. This research study was engrossed on biomechanical analysis of judo techniques, aims to provide a comprehensive understanding of the kinematic properties and its interactions involved in the execution of judo techniques. By rigorously analysing the selected techniques using motion capture technology and biomechanical principles, the researcher seeks to contribute to the development of evidence-based training methods and competition strategies in the field of judo. Additionally, by integrating the biomechanical findings with practical insights from experienced judo practitioners and coaches, this research aims to enrich the body of knowledge in the field of sports biomechanics and its applications in combat and sports performance.

### **Rationale of the Study**

Judo, characterized by its dynamic and complex techniques, stands as an Olympic sport where the mastery of biomechanics plays a pivotal role in achieving success on the mat. This research embarks on a journey into the world of Judo techniques with a specific focus on kinematic variables. Kinematics, the branch of biomechanics that deals with the motion of objects without consideration of the forces causing the motion, provides a unique lens through which we can decipher the intricacies of Judo movements. This study seeks to unravel the nuances of Judo techniques by delving into the kinematic variables that govern the execution of throws and manoeuvres. Kinematic variables such as joint angles, angular velocity, and angular displacement are crucial elements in understanding the precision of Judo

techniques. Investigating these variables allows for a detailed analysis of how judokas manipulate their bodies and those of their opponents during throws, providing insights into the fine-tuning required for successful execution. By isolating and interpreting kinematic variables, this research aims to identify key performance indicators (KPIs) for different Judo techniques. Understanding which kinematic factors contribute most significantly to successful throws can guide training regimens, enabling athletes to focus on aspects critical to achieving optimal performance. A comprehensive analysis of kinematic variables allows for the development of tailored training programs. Coaches can use this information to design drills and exercises that specifically target the kinematic elements essential for mastering particular Judo techniques, thereby optimizing the efficiency of training sessions. Exploring kinematic variables facilitates a comparative analysis of different Judo techniques. By contrasting the kinematics of throws, researchers can discern the unique biomechanical signatures associated with each technique, contributing to a deeper understanding of the diverse range of movements within the art of Judo. As biomechanics continuously evolves, the study of kinematic variables in Judo techniques adds to the broader scientific understanding of human movement. This research contributes to the academic discourse, offering insights that extend beyond the realm of Judo and into the broader field of sports science.

### **Sports and Sports Bio-Mechanics**

The field of sports is subject to its remarkable scientific changes. The research has revolutionized sports and high-tech innovation through contributions from various disciplines such as sports biomechanics sports medicine, sports engineering, Exercise physiology and sports psychology. Different methods try to find talented people and train them near suitable environments. They argued that sports are a barrier to physical genetics in a relatively structural and institutional context. Currently it seems a national honor to win competitive sports because every country strives to win. Some countries even try to express the potential of their potential ideology through achievements in the field of sports. To bring success, scientific methods limit every fraction of a centimeter of energy from one athlete to one machine per second. Efforts

are now being made to set up research laboratories everywhere so that not only donkeys but also human beings can find ways and means to accelerate their performance in sports. The best is distinguished by various sports training systems, new sports techniques, strategies, state-of-the-art equipment, suitable conditions and other compounds. Indeed, sports have now become a very complex phenomenon. Sports are bounded with psycho-motor activity. It has both technical and tactical dimensions, besides physical, social and mental aspects. In this modern era of competitions, the technical preparation is as much important as in elite performance and winning a competition. Now the athlete train not only to play the game, but to win the game and for winning the game, it is not only the proficiency in skills which brings victory but more important is the perfection in technical execution. Technical excellence for sports performance can only be achieved by applying the validities of physics in the right way, and this become achieved by the application of Biomechanics in the field of sports and athletic training.

The study of structure and function of the biological system by the rule of mechanics applied to muscular activity. The concept of biomechanics aroused from the ancient era. The term Kinesiology, which is used interchangeably with biomechanics, is a combination of two Greek words kinein means “to move” and logos mean to “discourse”. So it as “ a discourse on movement”, and it defined as, the study of muscles and body movement related to anatomy and mechanics. The Greek philosopher Aristotle (384-322 BC) is considered as the father of kinesiology. He is wrote several treatises, including *De Partibus animalium* (On the Parts of Animals) and *De Motu Animalium* (On the movement of Animals) who described for the very first time the actions of the muscles and disposed them to geometric analysis. Another Greek mathematician and physicist, Archimedes (287-212 BC) developed hydrostatic principles related to floating bodies that are still accepted as valid in fluid mechanics or the biomechanics of swimming.

The great artist, engineer, and scientist Leonardo Da Vinci (1452-1519) described the relationship between the center of gravity and body balance. He explains the mechanics of standing, walking, and jumping. Italian scientist Galileo Galilei

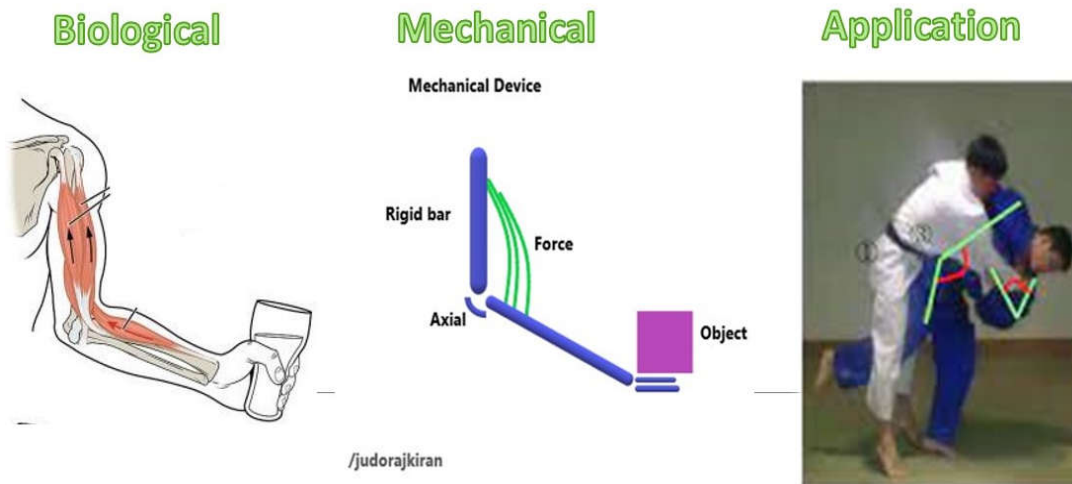
(1564-1643) demonstrated that acceleration of a falling body is not proportionate to its weight and that the relationship of space, time, and velocity is the most important attribute in the study of motion. Many other ancient scientists such as Alfonso Borelli (1608-1679) stated that bones act levers. Isaac Newton (1642-1727) established modern biomechanics and his laws of inertia, acceleration, and action reaction are major and valid laws of modern biomechanics. Biomechanics were concerned with integrating in to their studies a number of different disciplines such as ‘structural and functional biomechanics’ ‘exercise physiology’, and ‘motor behavior and control’.

Mechanics is a branch of Physics and engineering that deals with the mechanical aspects of forces responsible for maintaining an object or structure in a fixed position, as well as with the description, prediction, and causes of motion of an object or structure. The term biomechanics is a combination of two words “Bio” and Mechanics” the word bio means living organism and mechanics is a branch of physics. When the laws and principles of mechanics applied on the living organism called biomechanics and the actual application of biomechanics in to the field of sports which become Sports Biomechanics.

Mechanics have two major fields, Statics and Dynamics. Statics, which considers rigid bodies that are in a stable state of equilibrium and Dynamics, which studies objects that are in motion. Both of this field includes the further division as Kinematics and Kinetics. Kinematics and Kinetics are divisions of Biomechanics. Kinematics deals with the geometry of motion, and Kinetics deals with cause of motion. Kinematics explains the description and explores the displacement, velocity, and acceleration etc. of motion of an object whereas kinetics explains the force and its effects on an object.

**Figure 1**

*Application of mechanical principles to athletic performance*



Sports Biomechanics usually refers to how the musculoskeletal system in athletes works under different conditions. Biomechanical engineering principles, physics, and other types of mathematical analysis methods will be applied to study the capabilities and limitations of the athletic performance. Sports biomechanics is a subdivision of biomechanics, which is a branch of man and biology. Mainly sports and exercise biomechanics focus on the analysis of the physiological mechanics of athletic movement. This includes how the forces interact and the effects of these forces on the body and within it. In other words, the biomechanics of the sport examines and explains why and how the athletic body moves. It involves the interaction between an athlete and equipment in a sport environment. In general, the primary goals of sports biomechanics are to improve athletic performance by identifying and applying the optimal technique, prevent chances of sports injuries and rehabilitation.

### **Importance of Sports Bio mechanics**

Understanding biomechanics is crucial for comprehending the underlying principles of sports performance, enabling efficient practice and skill development. Biomechanics knowledge plays a pivotal role in physical training, aiding in the improvement of motor qualities essential for athletic prowess. In the realm of sports,

biomechanics becomes a tool for self-evaluation, empowering athletes to critically analyze and refine their own performances. Moreover, this knowledge contributes to the formulation of scientifically grounded advancements in the rules and regulations governing sports. The development and modification of techniques are guided by biomechanical considerations, allowing athletes to leverage mechanical advantages and address disadvantages in their performances. Beyond the individual level, biomechanical insights facilitate the selection of players based on their physical capabilities. Additionally, informed decisions about equipment, chosen for its ability to provide maximum mechanical benefits, are guided by biomechanical understanding. The application of biomechanics extends its support to the prevention, protection, and rehabilitation processes in sports. In the realm of physical education and sports coaching, biomechanics knowledge is integral, serving as a cornerstone for diagnostic teaching and coaching practices. Overall, the multidimensional application of biomechanics significantly contributes to the optimization of athletic performance, player selection, and the overall evolution of sports.

### **Bio-Mechanical Analysis of Motor Action**

Sports biomechanics allows detailed analysis of sports movements. With these results the mechanics of movements can be improved to allow better sports performance and or less injury risk. Sports biomechanics is often confronted with very special requirements: Analysis often has to be done at the place of sports performance (in the field) High performance athletes need to get analyzed in competition to get relevant information Results have to be communicated and be understood by athletes and trainers to make use out of them in training.

Bio mechanical analysis enhances the effectiveness or efficiency of a technique. The techniques are being analyzed by phase wise pre-execution phase, execution phase and post execution phase in terms of their purpose, objectives, forms etc. Technique is a model of performing movement of series of anatomical segments which is performed in a particular sequence with specific spatial dynamic and time bound dynamic structure.

Sports biomechanics often focuses on improvement of sports performance to reach extraordinary results. Often Olympic athletes get sports biomechanical assessment to reach optimal movement performance. As athletes and their conditions are very individual, sports biomechanical assessments need to be individual to the athlete and the specific question. Methods used in sport biomechanics can differ and mostly include 2D or 3D kinematics, kinetics, EMG or pressure. A special requirement in high performance sports is the analysis in competition, where no markers or sensors can be used. Especially in this field the unique capabilities of Simi systems have enormous advantages.

### **Kinematic Properties**

It refers to the characteristics and attributes of motion without considering the forces or torques that cause that motion. In the context of physics and engineering, kinematics is the branch that deals with the description of motion, including concepts such as displacement, velocity, acceleration, and time. The kinematic properties of an object or a system provide information about its motion, but they do not involve the study of the forces that may be acting on it.

The basic kinematic properties include: Displacement: The change in position of an object in a particular direction, Velocity: The rate of change of displacement with respect to time. It has both magnitude and direction, indicating the object's speed and the direction of its motion, Acceleration: The rate of change of velocity with respect to time. Like velocity, acceleration has both magnitude and direction and Time: The duration over which motion occurs. Kinematic variables investigate the description of an object's motion without reference to the object's cause of motion. The spatial and temporal aspects of human motion are described using kinematic variables. Any (or all) of these variables could be employed in a kinematic analysis.

### **Scalars and Vectors**

The primary distinction between displacement and distance measures is that displacement is a vector quantity whereas distance is a scalar quantity. Before delving more into the topic of displacement and distance, it's vital to understand the distinction

between scalar and vector quantities. Scalar quantities are defined solely by their magnitude, whereas vector quantities are defined by both magnitude and direction.

### **Time**

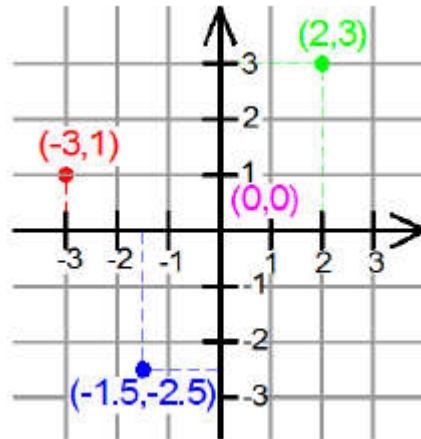
Time is one of the most basic aspects of kinematic analysis and it is essential for describing the temporal characteristics of human movement. There are several different ways of describing temporal characteristics. First, we can describe time either as relative or absolute. Relative time describes components of movement as a percentage of the movement time, whereas absolute is the actual time measurement (e.g. milliseconds, seconds, minutes, hours, days). While different scales of measurement can be used to describe absolute time, when using time in kinematic calculations it is important to use the SI unit of seconds (s).

### **Position**

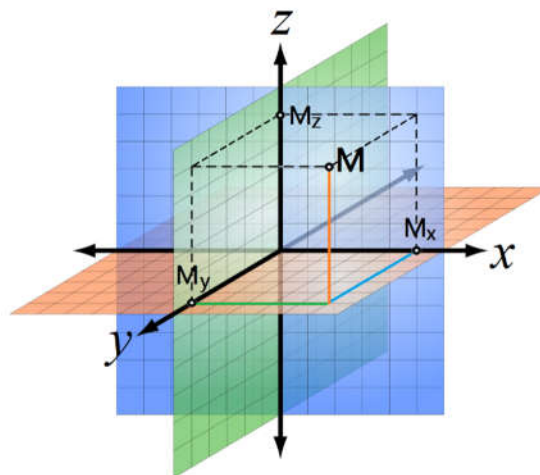
Along with the variable time, position is one of the most basic kinematic variables. Position is described as the location in space relative to some reference point. To describe position typically a Cartesian coordinate system is used. The Cartesian coordinate system identifies a point in a plane by a set of numerical coordinates that are the signed distances to the point from two fixed perpendicular lines. Each of these fixed perpendicular lines is called an axis (plural axes) and the point where the lines meet is called the origin. The Cartesian coordinate system can be located anywhere, but usually it is oriented in a location that makes sense relative to the movement. For example, the vertical axis, anterior-posterior and medio-lateral directions. With the coordinate system centered at a location where force is measured (force plate). The SI unit used for linear position is the meter (m) and position can be described as two-dimensional (2D) or three dimensional (3D). For simplicity, biomechanists often analyze planar motion separately. For example, it is common to examine only the sagittal plane in running or walking.

**Figure 2**

*Cartesian 2D coordinate system for positioning*

**Figure 3**

*Cartesian 3D coordinate system for positioning*

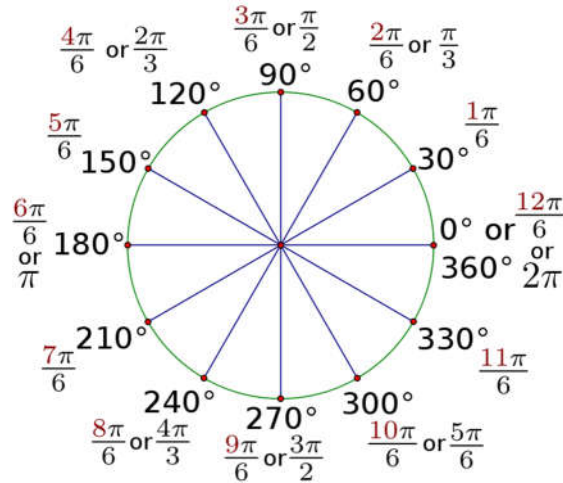


### Angular position

Angular position is the angle through which a point or line has been rotated about a specified axis on the cartesian coordinate. The SI unit used for angular position is the radian (rad). However, degrees (o) are often used to describe motion because they are used more frequently in everyday life and hence tend to make more intuitive sense to many individuals. It is important to note that when making many calculations it is essential to use radians

**Figure 4**

*Angular Motion expressed as radians*



### **Displacement and Distance**

The terms "displacement" and "distance" refer to how far an object has moved. Both linear and angular words can be used to indicate displacement and distance. Linear displacement/distance is movement anywhere inside the Cartesian coordinate system, whereas angular displacement/distance is movement around the origin. When it comes to displacement and distance.

### **Velocity & Speed**

Velocity and speed are measures of how fast an object is moving. Velocity is the vector version of this quantity and speed is the scalar quantity. Velocity and speed can be expressed in both linear and angular terms, with the only difference being that with angular velocity/speed the movement is a rotation instead of along a linear path. Velocity is calculated as the displacement of an object divided by the amount of time that it took for the displacement to occur .

The equation for velocity are as follows:

$$\text{Linear velocity: } v = d/\Delta t$$

Where  $v$  = linear velocity (m/s),  $d$  = linear displacement (m),  $\Delta$  = change in and  $t$  = time (s)

Angular velocity:  $\omega = \theta/\Delta t$

Where  $\omega$  = angular velocity (rad/s),  $\theta$  = angular displacement (rad)  $\Delta$  = change in and  $t$  = time (s)

Speed is calculated as the distance an object has moved divided by the corresponding change in time.

By analyzing these kinematic properties, one can describe and understand the motion of objects without delving into the underlying forces or causes of that motion. Kinematics is essential in various fields, including physics, engineering, biomechanics, and sports.

### Elucidation of Judo

Judo is a magnificent and enthralling fighting sport that necessitates physical prowess, mechanical application, and mental discipline. It entails techniques that allow a judoka to raise and toss his opponents onto their backs from a standing position. It involves techniques that allow a judoka to pin his opponent to the ground, control them, and apply various choke holds or joint locks until they submit.

Judo is derived from two Japanese words: Ju, which means "gentle," and do, which means "path." Judo emerged in Japan over hundreds of years as a derivative of many martial arts developed and employed by the samurai and feudal warrior class. Although many of the methods of judo were derived from disciplines that were intended to injure, maim, or kill opponents in actual field battles, the techniques of judo have been adapted so that judo students can safely train and use these techniques without



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injuring their opponents. Judo, unlike karate, does not use any kicking, punching, or striking methods. Judo, unlike aikido, does not entail applying pressure on the joints in order to throw an opponent. Unlike kendo, judo does not use any equipment or

weapons. Judo is just two people who, by gripping the judo uniform or judogi, strive to subdue each other using the forces of balance, power, and movement. As a result, it is straightforward and straightforward. However, in its simplicity lies its complexity, and mastering even the most basic of judo techniques requires a significant amount of time, effort, and energy, as well as rigorous physical and mental training

Judo, on the other hand, is much more than just learning and applying combat skills. Judo is the most popular fighting sport in the world, and it is a fantastic system of physical, intellectual, and moral instruction in its entirety. Judo is the second most popular sport in the world, behind soccer, in terms of sheer numbers of participants. Judo is the largest sport in the world in terms of national organizations, with the International Judo Federation, or IJF, having the most member nations. Many countries' physical education systems include it, and it is practiced in local clubs, junior high and high schools, colleges, regional and national training centers, and a variety of other settings throughout the country across the world. Millions have discovered the spectacular enriching sport, and way of life, we know of as judo.

Judo is a strenuous and physically demanding sport. Judo techniques aid in the development of basic and fundamental physical fitness in a variety of ways, including strength, flexibility, agility, speed, dynamic and static balance, explosive power, and endurance. Active attack and defense training aids in the development of response time, coordination, and general physical self-confidence. Judo trainees get physically bigger, stronger, and faster as a result of their training. The physical advantages are evident, but there are also psychological advantages. Judo training helps students of all ages and levels develop character, confidence, and courage while also teaching discipline and philosophy. Adults and children who practice judo gain knowledge about themselves and the world around them while also strengthening their bodies.

The concept of judo, which emphasizes "maximum efficiency with little effort," has piqued interest in the early stages of a throw, or the mat time when the opponent's balance is influenced. All judo throwing methods have three basic phases: kuzushi, which is defined as disturbing an opponent's balance or simply preparing them for a throw, tsukuri, which is the process of fitting into the throw, and kake, which is the actual throwing technique. The kuzushi and tsukuri phases are difficult

to distinguish in most throwing methods, including ippon seoi-nage. Although it is widely recognized that kuzushi always comes before tsukuri, the exact point where kuzushi ceases and tsukuri begins is debatable (**Harrison, 1952; Imamura et al., 2006; Kano, 1986; Kim and Shin 1983; Koizumi, 1960**).

Judo is still one of the most widely practiced sports in the world. International competition is now being held by 187 national affiliates of the International Judo Federation (IJF). Medalists from 19 different countries competed in the 2004 Olympic Games in Athens, Greece. Judo's underlying principle of "maximum efficiency with lowest effort," or emphasizing appropriate mechanics and technique above muscular strength, is congruent with the biomechanical approach to researching judo. However, determining perfect judo mechanics is difficult, especially because judo success is primarily driven by both the opponent's and one's own movements. A number of contact sports are similar to judo in this regard and have also received little attention.

### **Contributions of Prof. Jigoro Kano**

Professor Jiuro Kano was a well-known Japanese educator and the father of contemporary sports. Jigoro Kano, however, was the founder of Judo. He was born on October 28, 1860, into a family that was moderately well off, at least well enough to get Jigoro into the elite Tokyo Imperial University. In Nada, Shiga Prefecture, near the Biwa Lake in central Japan, his grandpa started the family business of making sake. In fact, it was the Fujimi-cho Dojo, which served as the Kodokan in the second part of the 1880s, that organized the other sake makers in the area to assist fund the Fujimi-cho Dojo.

The same business was not passed on to Jigoro's father because he was not the eldest son. Even yet, his father made a good living in Kobe, Jigoro's birthplace, as a Shinto priest and a high-ranking government official in charge of shipping line purchasing agents. This branch of the Kano family was responsible for the construction of Japan's first steel ships, coastal vessels meant to transport sake. Jigoro was the third son in a family of three boys and two girls, and he was physically frail throughout his youth. He was beaten up so frequently by local bullies that he vowed to fortify himself in every manner he could. This insatiable need to understand how

to defend himself eventually led to the creation of Judo. What would have occurred if Jigoro Kano had been a large behemoth instead of the 5-foot-2-inch, 90-pound wuss at his teenage

During Jigoro's childhood, jujitsu was thriving. The mid-nineteenth century is often referred to as the "golden age" of jujitsu. So, Jigoro anticipated his move to Tokyo, where the majority of the jujitsu activity took place, with trepidation. His father ordered him to go to the capital on one of the sake-carrying steel ships when he was 17, but he refused and insisted on travelling on land. His father gave in, which was a good thing because the ship he was to travel on sunk in rough seas en route to Tokyo. At the age of 18, Jigoro enrolled at Tokyo Imperial University the next year.

He would go out in search of an osteopath when he wasn't in class or studying because they had all had jujitsu instruction. He was still preoccupied with learning the art of manly self-defense, and he believed that jujitsu offered him the best chance. His search eventually took him to the door of Teinosuke Yagi, a bone doctor in Nihonbashi who offered to introduce him to a jujitsu instructor in the area.

Jigoro Kano began jujitsu training when he was 17, but his master, Ryuji Katagiri, thought he was too young for rigorous instruction. As a result, Katagiri merely assigned him a few formal study activities and left it at that. But the tenacious young man was not to be deterred, and he eventually wound up at the dojo of Hachinosuke Fukuda, a master in the Tenjin-Shinyo School of Jujitsu whom Dr. Yagi had recommended. Fukuda emphasized technique above kata, or formal exercises. His approach was to explain the exercises but focus on free-style fighting during the practice sessions. Under Fukuda's influence, Jigoro Kano's emphasis on "randori" in Judo was surely born. Fukuda and a subsequent sensei named Likubo were responsible for the Kodokan's practice of teaching beginners the fundamentals of Judo, then having them engage in randori, and only after they had reached a particular degree of proficiency, teaching them the official kata.

Jigoro began training in Fukuda's dojo in 1879, and a year later, the jujitsu teacher got dangerously ill and died at the age of 52. The 19-year-old quickly joined a branch of the Tenjin-shinyo-ryu led by Masatomo Iso, a 62-year-old jujitsu

instructor. Iso's dojo was noted for its skill in kta and was located in the Kanda area of Tokyo, in the city's heart. Iso was barely 5 feet tall, yet he possessed a muscular body and an energizing personality. Jigoro Kano spent the next two years eating, drinking, and sleeping jujitsu, training at all hours of the day and night.

Things had become so terrible that he was having jujitsu nightmares, shouting jujitsu phrases in his sleep and kicking out at his blanket. Because of his dedication and promise, the sensei quickly appointed him as an assistant. Jigoro taught a group of 20 or 30 students, beginning with kata and progressing to free combat. Kano had mastered Tenjin-shinyo-ryu jujitsu by the time he was 21 years old in 1881. But, like Fukuda before him, Iso fell ill, and Kano opted to leave, believing that he still had a lot to learn and preferring to study rather than teach. The following step appeared to be a foregone conclusion.

Tsunetoshi Likubo, master of the Kito School of Jujitsu, introduced Jigoro Kano to his dojo, where he began training. Kano would work out alone even if no one else showed there. Like Fukuda, Likubo emphasized free fighting and was particularly adept at teaching nage-waza.

### **Jujitsu to Judo**

During his early jujitsu training days, Jigoro Kano experimented with novel throws and became increasingly interested in how to reorganize jujitsu into a new system. He came up against a large, 200-pound bruiser named Kenkichi Fukushima while practicing at the Tenjin-shinyo Training Hall. The lightweight youth always lost to the bigger man despite being outweighed by 100 pounds. He was so desperate to beat Fukushima that he studied anything he could get his hands on — sumo tactics manuals, foreign training books, and so on. Finally, Jigoro devised a new method.

He charged in low the next time he faced his massive opponent, grabbed Fukushima onto his shoulders, turned him around, and effortlessly tossed him to the mat. His revolutionary throw was quickly dubbed "kata-guruma," or shoulder twirl. He also practiced "uki-goshi" (rising hip throw) and "tsuri-komi-goshi," two more throws (lift-pull hip throw).

Rather than creating a new system, the original plan was to reform jujitsu. Kano was fully aware of the flaws, but believed that by eliminating them, jujitsu might be beneficial to young men not just as a martial art, but also as a type of physical education, as well as spiritual training and discipline; in short, a valuable preparation for daily life.

He dedicated himself to developing a scientifically based method of reformed jujitsu that combined fighting training with mental and physical education. He took Kito-"katamewaza" ryu's (mat techniques) and "atemi-waza" (throwing techniques), keeping only those that followed scientific principles and dismissing the others. All potentially damaging and risky procedures were abandoned. When Jigoro Kano, at 22 years old, removed nine of his private pupils from the Kito-ryu Training Hall and opened his own dojo in Eishoji Temple in February 1882, Judo didn't appear out of nowhere. In fact, Kito-ryu master Likubo visited the temple twice or three times a week to assist Kano's disciples in their studies. As a result, they were getting more jujitsu training than Judo training.

Two years would pass before the first Kodokan's bylaws were drafted. Much has been written about the early days at Eishoji, and it is this temple that most people consider to be the birthplace of Judo. The change from jujitsu to Judo was gradual but steady, and it's difficult to identify the exact moment when that small group of pupils realized they were learning Judo instead of jujitsu. It could have been the day Kano defeated Likubo for the first time. Until then, he had never beaten the Kito-ryu stylist. However, during randori practice that day, Kano blocked every move performed by Likubo, then summoned his "uki-waza" and "sumi-otoshi" to throw the jujitsu.

"Force your opponent to make his body rigid and lose his balance, then attack when he is powerless," Kano advised. "From now on, you teach me," Likubo answered. Kano ultimately earned his accreditation as a Kito-ryu master after Likubo retired as a teacher. Every time Likubo arrived to instruct at Eishoji's 12-mat dojo, training became a little more aggressive than usual. And the tablets would fall to the ground!

**Figure 5**

*Judo Class: Prof. Jigaro Kano teaching uki goshi*



Source: <https:hampsonlife.com/wdob/mai/people/jigarokano/kano16.jpg>

## **Kodokan**

The Kodokan was founded in 1882, and its Dojo, or training hall, was just 12 mats in size, with only nine pupils in the first year. Today, the Kodokan, which recently celebrated its 70th year (note: as of 1964 publishing date), has a 500-met, 100' x100' workout hall, and a student body of millions of men and women, young and old, regardless of race or nationality.

Harai goshi was one of Yamashita.'s fervent visions performed on S. Nagaoka during the late Yamashita's final days. Professor Kano's vision of the International Federation of Judo comes to fruition, with his son, the current president of the Kodokan, as its president and the Kodokan as its headquarters. Our hearts are filled of great emotion when we reflect on the past. Many stories and anecdotes are related about Professor Kano's struggles and the enormous pains he went to when teaching Judo in the early days of the Kodokan, but we regret that we are unable to include them due to space constraints.

**Figure 6**

*Eishoji Temple, the birthplace of Kodokan Judo*



Source: <http://judoinfo.com/photos/eshojitemple>

Despite its young and limited size, the Kodokan made rapid progress, gaining significant public awareness in a few years after enduring every hardship and overcoming numerous obstacles. Then, in 1868, it won unchallenged field leadership in a dramatic fashion. The old Jujitsu schools were making a resurgence around that period, as the country's social situation stabilized. Because of its role, the Tokyo Metropolitan Police Board took a keen interest in the resurrection of Jujitsu, as well as Kenjutsu, Japanese fencing, and other martial arts. The public's attention was drawn to the new Kodokan Judo.

Its tenets and slogans, as well as its great idealism, were admired by everyone. However, ancient Jujitsu men, notably the then-famous master Hikosuke Totsuka, who commanded a big following, viewed it with mistrust, suspicion, and even scorn for its practical qualities in battle.

The Totsuka School and the Kodokan established an intense rivalry. A big competition was organized between the two institutions in 1886 under the supervision of the Chief of Metropolitan Police. This was a game-changing clash. The Kodokan

would have died if they had lost. However, in that tournament, in which each school sent 15 selected men, the Kodokan won every match except two, which were drawn (note: it is tempting to speculate that such contests were more like duels than sporting events, considering the time period).

That stunning victory cemented the Kodokan Judo's supremacy over all Jujitsu schools, not just in terms of principles but also in terms of techniques. There are many important stories to be told from that time till now, such as the history of Judo's spread at home and abroad, but space does not allowed us to include them all here. "Classical judo represented a Quasi-fighting art," Draeger and Smith write, "with consideration given mostly to mining of mind and body via prescribed workouts; incorporated were features of physical education, self-defense, and competition. "Kano changed the word 'enemy' in jujitsu to 'opponent,' but he didn't aim to eliminate the self-defense values entirely. Physical education and self-defense have been pushed to secondary positions as a result of the present emphasis on competition, and the overall balance created by Kano has been lost."

The Kodokan Judo's technical formulation was completed around 1887, and its spiritual phase was gradually built up until it was perfected around 1922. In that year, the Kodokan Cultural Society was founded, and a social movement called "Seiryoku-Zen'yo," or Maximum Efficiency, and "Jita-Kyoei," or Mutual Welfare and Benefit, was launched (note: also means as You and I, shining together).

**Figure 7**

*Kodokan is the International University for Judo*



**Figure 8**

*Kano Jigaro: Shihan & Founder of Kodokan Judo*



Source: [https://en.wikipedia.org/wiki/kano\\_jigoro](https://en.wikipedia.org/wiki/kano_jigoro)

## **Principles of Judo**

Judo abide with some principles from the foundation of judo philosophy and techniques, guiding practitioners not only in combat but also in personal development and ethical behaviour. The following are the three principles of judo.

### **Ju-no-ri (Principle of Gentleness)**

It was previously said that we are never defeated if we maintain good posture and mental focus, and if we use the body in a natural and logical manner when performing movements and actions. It was also demonstrated how easily we might be defeated when our body's homeostasis is disrupted. The next step is to learn how to apply these two ideas in a judo match, namely how to deal with the opponent's power when it is utilized against us and how to win the match. The guidelines of this practice are known as ju-no-ri, or the kindness principle.

### **Seiryoku-Zenyo- ri (Maximum Efficient use of Energy)**

"Seiryoku-Zenyo (most efficient use of energy) is a concept that applies to all types of efforts and entails fully utilizing one's spiritual and physical resources to achieve a goal. The most effective utilization of the mind and physical power is Seiryoku-Zenyo. This is the idea that underpins both attack and defense in Judo, as well as the training process. Simply put, the most efficient use of energy can be stated as the most effective use of mind and body. In a nutshell, this can be summed up as "maximum efficiency." One of the key ideas of Judo is to make the best use of one's energy, but it's also crucial for reaching many goals in life.

"The primary teaching of Judo is the principle of making the best use of one's energy." To put it another way, it is the most efficient use of one's energy for a good cause. So, what does it mean to be 'good'? Assisting in the continuous development of one's community is a desirable thing, but opposing such progress is harmful... The concepts of 'Sojo-Sojo' (assist one another; yield to one another) or 'Jita-Kyoei' (continuous advancement of community and society) are used to achieve this (mutual benefit). Sojo-Sojo and Jita-Kyoei are likewise part of the greater good in this way. Judo's fundamental wisdom is this.

### **Jita-Kyoei-ri (Mutual Understanding)**

As long as we coexist, each member of society and the groups that make up society must work in harmony and collaboration with one another. Nothing is more vital than cohabiting in prosperity. If everyone acts in a spirit of mutual collaboration, everyone's work benefits not just himself but also others, and achieving this together would offer everyone delight. Activities should not be pursued just for the sake of self-interest. When a person realizes that his efforts will boost the prosperity of everybody, it is only natural for him to seek goodness in peace and cooperation. In other words, the concept of Jita-Kyoei, or mutual prosperity for oneself and others, is this wonderful principle of harmony and collaboration.

### **Aims of Judo**

Although the forms of Judo, Boxing, and Wrestling differ, they all have the common ground of having evolved naturally as physical disciplines. Judo is never mysterious: it can be done everywhere, at any time of year, and without any set numbers. It can be done not only as a sport, but also as a type of physical culture, and it can teach us the valuable art of self-defense at the same time. This will be detailed in greater detail further down.

### **Physical Development**

Every action in Judo has its own meaning and purpose. The types of actions are numerous, with all portions of the body being equally utilized in all directions, such as upward, downward, left, and right, with a considerable amount of movement being required. As a result of Judo training, one's muscles and bones naturally develop stronger, and one's internal organs are reinforced, resulting in a robust and harmonious physique.

Furthermore, because Judo is a close-knit sport in which competitors compete for mastery in arts, one must constantly be ready to do his best right away against the opponent's trickery. As a result, everyone's body will grow to be completely free and attentive in the event of an emergency.

## **Mental Development**

When one is properly taught in judo, one develops a noble and refined character without even realizing it. The first benefit of judo training is the fundamental moral, namely, a high soul that dares to face challenges on one's own initiative—that is, a dashing spirit. Next, because judo necessitates the performance of bodily conflicts with the entire body and mind in sync, a strong will must be developed in order to control oneself and the opponent. By and by, stout-hearted, resolute, preserving, and self-processed characteristics, rapid and right judgment, and cautionary and circumspect thinking capacities will be trained. Furthermore, the expressive movements of judo can provide an artistic sense. And a humble and noble character will be cultivated by paying attention to every minute movement and adopting a push-and-go attitude toward the truth.

Judo students become earnest and serious as a result of the nature of the game, especially in competition, and the spirit of fine play is held in high regard in judo: to fight fairly and squarely, to obey the umpire's judgment completely, and to place greater emphasis on the attitude in the game than on the results. The brilliant spirit of a sportsman is naturally fostered from these intentions.

## **Self-defense**

In our daily social lives, we come across several physical and mental hurdles, and our lives are occasionally put in jeopardy. We can simply obtain physical and mental culture as well as the valuable art of self-defense by practicing judo.

## **Recreation**

Human beings have an innate desire to wrestle with one another. Judo is the best of the so-called grappling sports; if one is regularly trained in judo, grappling will be more appealing to him, and he will continue to practice Judo throughout his life.

## Fundamentals of Judo

### Dojo

Dojo is a Japanese word that means "workout hall," "practice hall," or "place to learn the way." It was originally used by Buddhist monks to refer to a place of prayer, but it may also refer to a meditation hall or a club. As you can see, it can mean a lot of different things depending on which martial arts you are studying. Because Judo is our sport, we refer to it as a Judo Dojo.

### Figure 9

*The Traditional Dojo*



In a conventional Judo Dojo, you must first and foremost be approved as a student by the instructor. You may be taken aback by your initial encounter with the Sensei. The essential distinction between a commercial school and a Dojo must be understood. The basis of the issue is the Sensei's Dojo, which he administers according to his own norms as the instructor. Japanese etiquette (reishiki) must always be followed to the letter. You can't possibly learn all of the rules at once. Instructors can be of any Black Belt rank; nonetheless, the greater your instructor's rank, the more respect you should show them.

A popular fallacy is that there is a religion associated with Judo, which is untrue. Judo does not teach any religion. Please keep in mind that Judo originated in Japan, is a Japanese sport, and incorporates many Japanese customs. To a Westerner,

these may appear unusual, even absurd. That is the point; individuals who believe this have no place in a Judo Dojo. The Judo Dojo should always have enough space for the players to have at least eight feet between them for safety. The ceiling should be high enough so that a tall player can safely do a high throw like Kata Guruma (shoulder wheel).

The Dojo's mat surface should be kept clean and in good repair at all times. You, as students, should assist the Sensei by vacuuming and mopping the Tatami on a regular basis. The Sensei has a lot to accomplish to keep the Dojo running. He appreciates any assistance in keeping the Dojo tidy. There are numerous mat types that can be employed. It is determined by what the Dojo can afford. Judo Tatamis can be found in more traditional Judo clubs (rice straw mats, three feet by 6 feet by 2 inches thick, with vinyl covering). These are quite pricey and should be avoided whenever feasible. If these are out of reach, a school wrestling mat can be substituted.

A well sized Dojo should have a fifty-foot area at the very least. This is to provide enough space for people to exercise without risking injury. A Judo Dojo with little or no space to train can stifle the development of advanced skills. The Dojo should always be a place where real Judo training may take place. You should enter any Dojo with a clear head and pay attention to all instructions given. In the Dojo, all students must be on their best behavior at all times: each student should maintain a high level of discipline. While in the Dojo, the higher-ranked students are expected to set an example for the lower-ranked pupils to follow.

A NAFUDAKAKE, or name board, is a typical component of any Judo Dojo. On the board, all members of the Dojo are listed by belt rank, with the most senior grades appearing first and progressing down the board. It is necessary to keep the board up to date in order for it to be useful. This item is not used in many American Judo Dojos. In addition, a photograph of Jigoro Kano should always be displayed in the KAMIZA area (JOSEKI) seat of honor. There should also be a place for Judokas to remove their shoes or slippers before entering the mat area.

## **Salutation (Rei)**

It's a way of greeting a partner or expressing gratitude to a teacher, senior, or dojo, for example. It is regarded as an important etiquette and method of respect execution. The importance of salutation stems from the idea that when you show respect to a partner, instructor, or senior, you will receive the most cooperation. An ordered, effective, and efficient manner of conduct has been established for usage in all Dojos through highly precise customs. When a Deshi (student) enters or leaves any Dojo, one of the first things they must learn is to do a Ritsu Rei (standing bow) in and out of the Dojo.

This Rei is not just a physical exercise, but also a mental one. This means that when a Deshi (student) enters the Dojo, he or she clears his or her mind of all evil and negative thoughts, and feels good about themselves with the intention of becoming a better person as a result of what they are about to learn, or what they have learned at the Dojo before leaving. When they are going to enter or depart the mat area, they are expected to Rei for the second time. Their minds should also be pure and fresh at this stage, with a drive to study and grow at ease with themselves. The third time they Rei is before and after a partner workout. This is done with great respect since we are asking our training partner for the pleasure of working out with you, and you are also stating that you arrive with a clean mind and have no goal of injuring you; if I or you are injured, there will be no ill feelings between us.

## **The Shisei (Posture)**

Shisei is divided into two categories: Shizen-tai and Jigo-tai. Shizen-tai (Natural Standing Stance) is made up of Shizen-hontai (Basic Natural Standing Posture), which is a natural and gentle standing posture. Migi-shizen-tai (Migi-shizen-tai) is a Japanese word (Right Natural Standing Posture) From the basic natural standing posture, the posture standing with right foot moved a bit rightward and forward. Hidari-shizen-tai (Left Natural Standing Position) is a standing posture in which the left foot is slightly advanced leftward and forward from the basic natural standing posture. Shizen-hontai Migi-Shizen-tai Hidari-shizen-tai

Jigo-tai (Defense Posture) is made up of Jigo-hontai (Basic Defensive Posture), which involves lowering the loins and opening both feet wide. Migi-jigo-tai (Right Defensive Posture) is a posture in which the loins are lowered and both feet are opened wide. Migi-shizen-tai

Hidari-jigo-tai (Left Defensive Posture) is a variation of Hidari-shizen-tai in which the loins are lowered and both feet are opened widely..

### **Ukemi (Break Fall)**

Ukemi is a set of techniques that allow you to fall or be thrown down safely, avoiding harm or shock from a violent impact with the mat. To lessen shock, the impact of a throw or fall method should be widely distributed throughout the entire body. Judo has a unique falling technique, and frequent practice improves personal safety and fitness. There are four different techniques for falling. Backward falling (Ushiro Ukemi), sideways falling (Yoko Ukemi), and forward rolling falling (Mae Ukemi) (Mae Mawari Ukemi).

### **Shintai (Advance Retreat)**

Judo walking methods, on the other hand, involve simultaneously moving judoka's legs, hips, and body forward or backward. A judoka cannot move the body while leaving one foot behind or advance the body while leaving one foot behind in judo. Advance-retreat movements, as the name implies, are the basic movements that allow you to move your body straight ahead, backward, left, or right to achieve the desired position.

Ayumi Ashi (normal walk), Tsugi Ashi (following feet), and Tsuru Ashi are the three styles of judo movement (Gliding feet). A judoka walks normally in Ayumi Ashi by not allowing his feet to move too far apart or too close together, by not allowing his body—head, shoulders, hips—to rise and fall, and by sliding smoothly across the floor. However, with the tsugi-ashi style, judoka could take a stride forward on our right foot, then bring our left foot forward far enough to keep the body in the right natural position. To put it another way, our left foot does not go ahead of our right

foot. It largely adheres to it. Tsugi-ashi literally translates to "following feet." In tsuri-ashi steps, the judoka moves from the left natural posture to the right natural position, as though their feet are gliding across the mat.

### **Tai Sabaki (Turning Movement)**

Tai Sabaki ('body-management') plays an important role in the execution of a technique. It assists a judoka in generating torque in order to achieve maximal angular velocity. It creates a set of procedures for bodily movement. Its purpose is to take a step away from the line of attack (not from the opponent) and put the person in a better position to counter. Using irimi and tenkan movements to 'move off the line' of assault rather than 'moving against' the attack is an example. There are four major circular movements that allow you to travel to one of the lateral positions, which gives you an advantage over your opponent. In front and back sides. Tai sabakki comprises 90-degree and 360-degree turning movements with both legs on the front and back sides of the torso.

## **Conceptual Framework of Judo Techniques**

### **Classification of judo techniques**

All judo techniques are categorized into three groups, each of which is further divided into subgroups. The three categories are as follows:

Nage Waza – Throwing Techniques

Ne Waza /Katame Waza – Grappling Techniques

Atemi Waza – Striking Techniques (Not Allowed in Competition Sport)



Scan QR Code for virtual demonstration

### **Throwing Techniques: Nage-Waza**

Nage-waza (throwing method) is a Japanese term for a grappling technique in which an opponent is lifted or off-balanced before being thrown to the ground. Throws typically entail a pulling and rotating motion, with the practitioner remaining balanced

on their feet - standing techniques (tachi-waza). When performing the throw, though, both fighters frequently end up on the ground. Sacrifice throws (sutemi-waza) are throwing methods that require putting oneself in an undesirable position, like as on the ground, in order to execute a throw.

### **Standing Techniques (Tachi-Waza)**

From a standing position, Tachi-waza (Standing techniques) are performed, which are further divided into Te-waza (Hand techniques), Ashi-waza (Foot / Leg methods), and Koshi-waza (Foot / Leg techniques) (Hip techniques).

### ***Hand Techniques (Te-Waza)***

Te-waza (hand techniques) are part of the Throwing techniques (Nage-waza) group and are efficiently done by throwing the opponent with the hands/arms. It starts from a standing position and includes body moving to disturb the opponent before throwing them. Even a tiny opponent can throw a large-statured opponent with these moves.

### ***Foot Techniques (Ashi-Waza)***

Ashi-waza (foot/leg techniques) is one of the throwing ways (Nage-waza). Throwing techniques using legs (AshiWaza) are classified into three types: sweeping, reaping, and hooking. The ashi-waza techniques are difficult to master, but when executed correctly, they are among the most beautiful throws in Judo.

### ***Hip Techniques (Koshi-Waza)***

The Throwing methods (Nage-waza) group includes Koshi-waza (hip techniques). The fundamental method of the koshi-waza is to drag or boddy the opponent off balance and then throw them with the help of the hip (over the hip).



### Sacrifice Techniques (Sutemi-Waza)

Sutemi-waza (Sacrifice Techniques) refers to techniques in which the performer descends on their back or side to throw the opponent. Back Sacrifice (Ma-sutemi-waza) and Side Sacrifice (Yoko-sutemi-waza) are two types of Sutemi-waza.

#### *Back Sacrifice (Ma-Sutemi-Waza)*

Sacrifice Techniques are classified as Ma-sutemi-waza, which translates to "rear sacrifice techniques." These techniques are named by the fact that in order to complete the throw, one opponent must drop to his back (sacrifice himself).

#### *Side Sacrifice (Yoko-Sutemi-Waza)*

The classification of Sacrifice Techniques is Yoko-sutemi-waza (Side Sacrifice), which translates to "Side Sacrifice Techniques." These methods derive from the fact that in order to complete the throw, one opponent drops on his side (sacrifices himself).



### **Grappling Techniques: Katame-Waza**

In most cases, Katame-waza (Grappling techniques) are used when both opponents are on the ground/mat, as opposed to Tachi-waza (Standing techniques), which are used when both opponents are standing. Kansetsu-waza (joint locks), Shime-waza (choking methods), and Osae-komi-waza are the three types of Ne waza techniques (Pinning techniques). Ne waza, which translates to "mat work," is occasionally substituted for katame waza, however this is misleading because all katame waza are performed while lying on the mat. From a standing posture, some strangle holds and joint locks can be applied. In grappling, the opponent is held, his joints are locked, his limbs are bent or twisted, or he can be choked, as the language suggests.

#### ***Pinning Techniques (Osaekomi-Waza)***

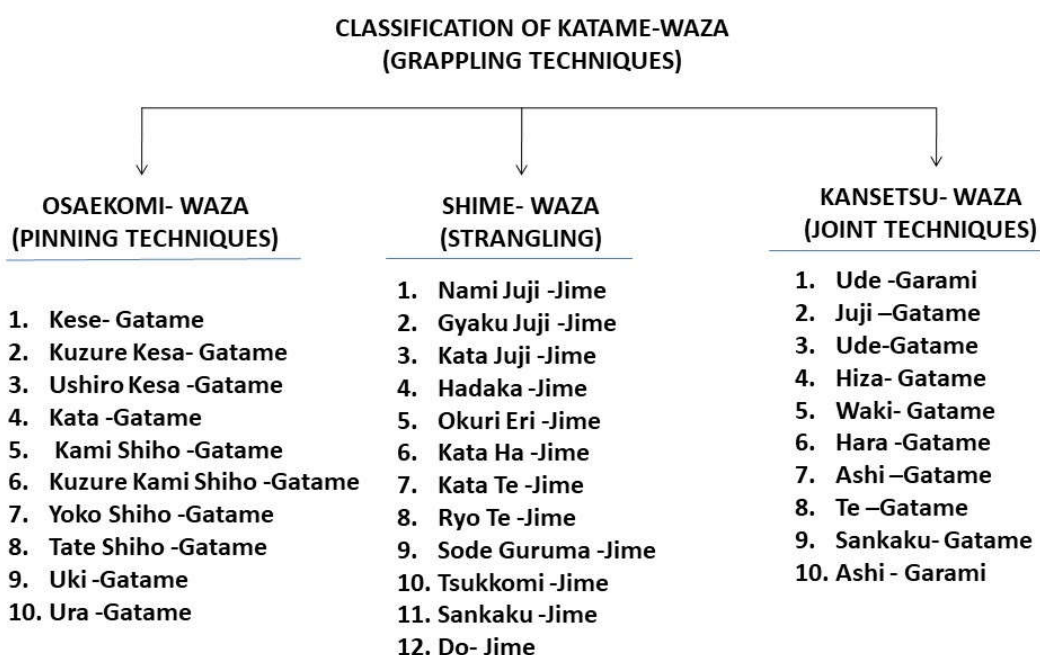
One of the groups of Katame-waza is Osaekomi-waza (Pinning Techniques) (Grappling techniques). When he holds another person on his back, these pins indicate various forms of hold down techniques.

### **Choking Techniques (Shime-Waza)**

Because of the possible threat to the opponent, choke execution is a subtle technique in practice. Chokes can be caused by compression of the neck veins, which prevents blood and oxygen from reaching the brain, compression of the trachea, or compression of the chest and lungs, which prevents breathing.

### **Joint Locking Techniques (Kansetsu-Waza)**

Kansetsu-waza (Joint locks) techniques include joint lock techniques against numerous joints of the body; however, kansetsu-waza against the elbow is the only kansetsu-waza used in modern judo. And one can grip the opponent's joint with one's legs, arms, and knees, then bend it in the opposite direction to lock it, rendering him virtually useless.



### **Striking Techniques (Atemi Waza)**

Atemi waza are strategies for temporarily incapacitating an assailant. The finger tips, the elbow, the knee, the ball of the foot, the toes, the heel, the forehead, or the rear of the head. Striking, punching, chopping, thrusting, jabbing, and kicking are all examples of the technique. It is further subdivided into Ude Ate (arm strikes) and

Ashi Ate (leg strikes), depending on whether the critical points were targeted with the hand or the leg. Making contact with a vital spot can result in discomfort, loss of consciousness, coma, disability, or death. Ate waza are only practiced in kata and never in randori or competition.

### **Kata (Form)**

Kata is a system of pre-arranged motions that teaches the fundamentals of attack and defence. It also includes the Ate waza techniques in addition to throwing and holding. This is only allowed in kata because the moves are pre-planned and each partner knows what the other is going to perform. Katas are divided into seven categories. Nage no kata (Nake no kata) is a Japanese (Throwing forms) Kakatme no kata (Grappling forms), Kime no kata (Decision forms), Goshin jutsu (Self-defense forms), Ju no Kata (Gentlemanly forms), Itsutsu no kata (five forms), Koshiki no kata (Ancient forms), Seriyoku Zenyo Kata ( maximum efficiency kata).

### **Randori (Free Practice)**

Randori refers to allowing practicing partners to compete against one another as though they were in a real match. They may throw, pin, choke, and apply joint locks, but they may not hit, kick, or use other combat-specific methods. The main rules of randori are that players do not damage each other and that they follow judo etiquette, which is required if one wants to get the most out of it. It can be used as a form of assault and defensive training or as a form of physical education. In either scenario, all movements are carried out in a relaxed manner while adhering to the principles of maximum efficiency.

If the goal is to improve attack and defense skills, focusing on proper technique execution is adequate. But, beyond that, randori is great for physical culture because it engages all of the body's muscles and, unlike gymnastics, all of its moves are forceful and executed with spirit. The goal of this systematic physical training is to perfect mind-body control in order to prepare a person for any emergency or attack, whether intentional or unintentional.

### **International Judo Federation (IJF)**

In July 1951, the International Judo Federation (IJF) was established. The IJF was founded by European and South American judo federations, as well as Argentina. Over the next ten years, countries from four continents became affiliated. On all continents, the IJF now has 200 National Federations. According to the International Judo Federation, judo is practiced by about 40 million individuals worldwide.

Since 2009, the International Judo Federation (IJF) has hosted annual World Championships and the World Judo Tour, which includes five Grand Prix, four Grand Slams, a master tournament, and a Continental open tournament.

### **Judo in India**

Gurudeva Rabindranath Tagore was enchanted by the performance of Mr. Jinnosuke Sano, a jujutsu expert from Shantiniketan, Birbhum, West Bengal, in 1921. Gurudeva had the unique opportunity to attend a demonstration of jujutsu and Judo in Japan while travelling from Canada to India. As a result, he made the required arrangements to bring Mr. Takagaki San, a Jujutsu expert, to Shantiniketan to teach Jujutsu to the guys, particularly the girls, in order for them to acquire this martial art for self-defense.

This innovative technique of self-defense piqued the interest of Shantiniketan students. Gurudeva was present to observe their instruction. Mr. Takagaki San lived in Shantiniketan for over two years, and his boarding, lodging, and travel expenditures were around Rs. 14000/- (Rupees Fourteen Thousand Only). Unfortunately, due to Mr. San's departure, he was unable to continue this training in Shantiniketan. As a result, after his departure from Shantiniketan, the Art lost its significance. The last Jujutsu demonstration by Shantiniketan boys and girls took place at the New Empire Theatre in Calcutta on March 16, 1931, at 6 p.m.

Late Raghunath Damodar Khaniwale began teaching judo in our country in 1940. He was a man who dedicated his entire life to the advancement of his noble Art (in our country), which is built with the technical body of Jujutsu and the training is conducted in the form of a competitive sport/with the goal of instilling the principle

of maximum efficiency for the advancement of the way of life. Because human action is the expression of the intellect and emotions, the study of Judo extends beyond the physical plane to include philosophy, life science, and the mechanism of the human body.

Kajou Judo Club was founded in February 1960 with ten members, and then in April 1960. Mr. R. Ban, the Japanese consul general in Calcutta at the time, brought three Japanese Judo experts, Mr. Teizo Kawamura, Yoshimi Osawa, and Akio Kaminga, to the Calcutta Judokas, who graciously staged a good Judo demonstration.

Mr. Kawabata, a Kodokan Judo Instructor, graded the Judokas in Calcutta in July 1964, and a Judo demonstration was staged at the police Training College in Barrackpore in December. Professor Token Sumi visited Calcutta in January 1968 and presented a demonstration on judo, Jujutsu, and Aikido. Calcutta Judo Club (Formerly, Kajou Judo Club) began operating in its own Tent on the Calcutta Maidan in October, 1961, with 72 Japanese Judo Mats supplied by Mr. H. Kabayashi, Consul General of Japan in Calcutta. Mr. Ryozo Nakamura and Tsgio Kobayashi, both Black Belt 5th Dan (Judo), conducted a Judo demonstration during the opening ceremony with the help of members of the Calcutta Judo Club, India's first Judo club.

Judo became mandatory in the West Bangal Police Force's training system on June 3, 1976. The Calcutta Police Authority also has good Judo Experts and a lovely Dojo where Judo can be practiced. It was in 1976 that the Netaji Subhas National Institute of Sports, Patiala, began offering one short course and one full regular course in Judo to our country's adolescents with the assistance of Japanese Judo Experts. The successful candidates are given Coach Certificates and are presently working as Judo Coaches in various states.

By this time, the Judo Movement in our country had grown in popularity, and state-level Judo associations had been founded, as well as an all-India body known as the Judo Federation of India, which had begun working for the advancement of this art. In Judo, there are two categories of Black Belt Holders at the moment. One batch has been graded by the Judo Federation of India with the assistance of its Technical Committee, which is currently led by Mr. K. Pastakia Black Belt 3rd Dan, and another

batch is being graded by Japanese Judo Experts, some of whom are Chief Judo Coaches of N.S.N.I.S., Patiala, and others have been delegated by the KODOKAN through the Japan Foundation from time to time.

It's encouraging to see that, in addition to the National Judo Championships held by the Judo Foundation of India, various State Bodies are now conducting Judo Championships or Tournaments where regular participants and newcomers alike can share their experiences. It is important to remember that while this Art may be adopted by our countryman while taking into account the geological, spiritual, economic, and religious aspects of mother-land, it will be prudent to rely on Japanese Experts for the technical aspects, as it is their National sport and their people who made this sport known to the rest of the world. On the occasion of the kodokan's Centenary Year, let us all hope that through the practice of judo, the bonds of brotherhood between all races on the planet would be strengthened even more. The Judo Federation of India, which was founded on July 21, 1966, is the governing body in India. Sonawala Building'2nd Floor, 65 Bombay Samachar Marg, Mumbai 400023, with a liaison office at Gate No.27, J.N. Stadium, New Delhi.

In 1986, the International Judo Federation granted India recognition. In 1986, India competed in its first international event at the Asian Games in Seoul, South Korea. Taking home four bronze medals. Since its first international appearance in 1986, India has competed in all major international tournaments, including the Asian Games, Asian Championships, Commonwealth Games, and Olympic Games. Judo is popular in all of India's states. This sport has also been adopted by the Services and paramilitary forces.

Judo is a popular sport that is practiced in schools and colleges. Universities, Police Games, National Games, and other similar events are held. In India, judo activities predominate in all age groups. There are competitions for Sub-Juniors (age group 10-14 yrs). Junior (14-18 years old) and Senior (above 18 years old) (age group 18 yrs, and above). Every year, the National Champion ship and State District Championships for Male and Female Judokas are held.

## **Judo Federation of India (JFI)**

In 1965, the Judo Federation of India was established. By 1970, India's judo community had grown to a substantial proportion, and JFI was finding it difficult to recruit additional professional judo coaches from the country. Trainers from overseas were unable to match the training needs of a vast and rising judo community, hence a large number of coaches from within the country were required. In 1976, Mr. Takashi Ogata paid a warm welcome to India and established a professional judo course at NSNIS, Patiala. Mr. Morio Suganami, another respected Japanese judo teacher, visited the judo community in India in 1979 and delivered recommendations and drew out certain action plans for the advancement of judo in India.

Indian gentlemen like Mr. Khaniwale, Dr. Pisolkar, and Mr. N.T. Bangera have made a significant and lasting contribution to the sport of judo. Mr. Jagdish Tytler, an Indian politician and president of the JFI, and Mr. L.K. Daga, an ex-general secretary, devised certain action plans to increase the participation of Indian judo teams at international events. In the 1986 Seoul Asian Games, India finally received its much-needed break, winning four bronze medals for the country. It was a watershed moment for India's judo squad, and India has been consistently performing at international judo events since then.

Several judokas from India have qualified for the Olympics. Mr. Sandeep Byala and Mr. Cawas Billimoria competed in the 1992 Olympic Games in Barcelona. Ms. Brojeshwori Devi qualified for the 2000 Olympic Games in Athens. Mr. Akram Shah represented India at the 2004 Sydney Olympic Games. Ms. Diviya and Ms. Kh. Tombi Devi qualified for the 2008 Beijing Olympics. Chaudary, Garima Participated in the 2012 London Olympics. Avtar Singh is an Indian businessman. Participated in the 2016 Olympic Games in Rio de Janeiro.

## Bio-Mechanics of Judo

Biomechanics plays a crucial role in enhancing the performance of judo practitioners by applying the laws and principles of physics to different judo techniques. This allows judoka to optimize their movements, generate maximum force, improve balance and stability, and execute techniques with greater efficiency. By analyzing the biomechanics of judo techniques, coaches and athletes can gain a deeper understanding of how forces and torques act on the body during different movements and leverage points. They can then make adjustments to technique and training methods to maximize power, speed, and effectiveness. Some specific examples of how biomechanics can be applied to judo include: Understanding the distribution of forces during throws to enhance the execution of techniques, Analyzing the optimal positioning and alignment of the body to maximize leverage and control over an opponent, Applying principles of rotational motion to improve the effectiveness of sweeps and takedowns, Utilizing the concepts of momentum and inertia to enhance the speed and efficiency of transitions and counters, Incorporating the principles of equilibrium and stability to maintain control and balance during gripping and off-balancing maneuvers, Implementing the biomechanical analysis of footwork and body positioning to increase the precision and timing of attacks and defensive movements.

### Figure 10

*Conceptualization of Biomechanical modelling in Judo*



By continually examining and applying biomechanical principles to judo techniques, practitioners can not only elevate their performance but also reduce the risk of injury by optimizing movement patterns and minimizing unnecessary stress on the body. This comprehensive approach to training can lead to a more efficient and technically proficient judo practitioner.

Newton's second law of motion states that a man with a bigger body mass can defeat a man with a smaller body mass. Aside from that law, there is another element that provides a larger opponent the upper hand. This is the powerful muscular force that a big man is normally endowed with. He can effortlessly carry or raise a heavy block, but a smaller man could find the task difficult. Although large muscle force is useful for breaking the opponent's posture in judo, muscular force does not contain all of the forces used in the sport.

Judoka must study the nature of muscular force in order to apply it properly and successfully. One of the most significant aspects of judo is that proper application of techniques requires entire body muscular activity, such as when performing seoinage. The same can be stated for strangling or pinning. It would be tough to defend yourself from your opponent's attack if you didn't have the ability to deploy all of your muscular might. As a result, we can deduce that exerting a strong force requires muscles to work together by utilizing the force of the waist and abdominal region. Expert judo is distinguished by a wide range of techniques. Because judo uses a variety of forces, including gravity, momentum, and friction, a judoka must not confuse muscular force for the only one that works. Judo will become difficult, heavy, slow, and inefficient if you do so.

It's critical to throw the opponent by exploiting his loss of equilibrium. The law of gravity is one of the laws at action here. The universe's bodies are attracted to one another. Let us now look at how the law of gravity applies to judo. The harder it is to move your opponent horizontally, the heavier he is. Vertical movement is significantly more difficult for a tori. On the other side, a greater gravitational force acts on him, causing him to fall. Gravity can be shown in judo as a force dragging the opponent downward.

If a judoka wants to make his opponent fall, he must apply kuzhushi, which causes his center of gravity to move outside the base. Then the force of gravity acts on him, causing him to lean or fall. Let's pretend a judoka and an opponent are facing each other. When the opponent approaches him and tries to grab his lapel. At the same moment, Tori pulls back as far as the opponent moves forward. If the opponent is unable to let his advanced foot advance again due to mental or physical limitations, uke will lean forward, lose his equilibrium, and throw him using gravity.

It goes without saying that the same thing will happen if the legs that support the trunk lose their stability. Tori may brush his advancing foot away if the opponent takes a longer stride forward than usual. By doing so, tori will be able to drop uke using the power of gravity rather than muscular strength.

Because of the weight advantage of the opponent, it may be difficult for a judoka to raise a larger opponent with his arms. However, as he leans forward, it is simple to support him at his center of gravity with hips. Consider how a seesaw may hoist a heavier person if someone sits further away from the fulcrum. After forcing the opponent to lean forward, use your hips to hold him at his center of gravity. A modest force can rotate him over the hips, regardless of how much weight he carries. If tori's hips are lower than her center of gravity, the opponent will be top heavy, and his own weight will work against him, forcing him to topple over. The fundamental purpose of hip throws like o-goshi is to entirely support the opponent's center of gravity with hips.

### **Mechanical Principles of Judo Techniques**

Judo techniques are based on the practical application of mechanics laws and principles. It is also necessary to grasp the mechanics of judo techniques in order to execute them correctly. Because judo methods are founded on scientific principles like as leverage and balance, a weak and small judoka can defeat a big judoka and powerful man.

The first principle is that never counter power with strength. If do this, the stronger judoka will always win. Remember that while an opponent is on balance, he

is strong, but when he is off balance, he is weak, so a judoka must maintain his own balance to exploit his opponent's weakness. If a man stands erect and keeps his center of gravity within a little circle drawn around his feet, he is in balance. Before performing a throw, a judoka must disrupt his opponent's equilibrium by moving his center of gravity outside the circle. For those who are unfamiliar with the term "Center of Gravity," it refers to the place at which a person's or an object's weight acts.

The action of levers is the second principle. Putting a crowbar under a heavy object makes lifting it considerably easier. The fulcrum of the lever mechanics is the point at which the object spins, and the rod consists of one end for effort and the other end for resistance. The same process was employed in all of judo's throwing techniques (Nage waza). When a judoka lifts an opponent on his hip and throws the opponent with a forceful pull with his arms, the Hip acts as a fulcrum and the weight of the opponent acts as resistance. The resistance you lift multiplied by its distance from the fulcrum equals the effort you exert multiplied by its distance from the fulcrum. The Mechanical Advantage of the Lever is defined as the resistance divided by the effort. (There is a third type of lever that does not have a Mechanical Advantage, but this is unimportant.)

When a judoka applies this to twisting an opponent around a line drawn perpendicularly down through his middle, it sees that the wider hands are apart when grabbing him for this reason, the larger your Mechanical Advantage will be. This will be seen in the form of throws. Take use of any mechanical advantage you can. The idea, according to Dr. Kano, is "Maximum Efficiency, Minimum Effort." The direction of pulls and the timing of attacks are equally critical to success.

### **Statement of the Problem**

This study investigates the relative importance of selected kinematic factors and its dominance on selected judo techniques in relation to competitive weight categories; thus, the study's problem was expressed in the form: ***“Bio mechanical analysis of selected judo techniques: interpretations on kinematic variables in accordance with competition weight categories”***

### **Objectives of the Study**

The research was carried out with the following objectives

1. To ascertain the kinematic characteristics of the judo techniques chosen.
2. To determine the influence of weight categories on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships.
3. To investigate the differences in kinematics among the judo techniques chosen with respect to the weight categories in the All-India Interuniversity level judo championships.
4. To quantify the kinematic properties of the judo techniques chosen.
5. To compare specified kinematical characteristics between various weight categories.
6. To determine which judo techniques, offer more kinematic benefits relying on the weight categories.

### **Delimitations of the Study**

1. The research was limited to nine judo techniques listed below.
  - i. Ippon-Seoi–Nage (SON)
  - ii. Seoi – Otoshi (SOO)
  - iii. Tai – Otoshi (TOS)
  - iv. O- Ghoshi (OGO)
  - v. Harai Goshi (HRG)
  - vi. Koshi Guruma (KOG)
  - vii. Osoto Gari (OSG)
  - viii. Uchimata (UMA)
  - ix. Ouchi Gari (OUG)

2. The research comprised on the collected primary as well as secondary videos of selected Judo techniques performed by the participants in All India interuniversity Judo championships of a period from 2017 to 2022.
3. The Judokas participated in all India interuniversity were the subjects of the study for the required practical application of the selected judo techniques.
4. The analysis was delimited to the kinematical variables listed below.
  - i. Angular Velocity (V)
  - ii. Angular Displacement (D)
  - iii. Movement Time (Mt)
  - iv. Height of CoG (HCoG)
  - v. Angle of Hip Flexion (AHJ)
  - vi. Angle of Knee Flexion (AKF)
5. The research further delimited to the competition weight categories specified by IJF  
  
Light Weights: Below 60 KG, 66 KG and 73 KG  
  
Middle Weights: Below 81 KG and 90 KG  
  
Heavy Weights: Below 100 KG and Above 100 KG
6. The research was then delimited to the motion capture kit for mechanical analysis.

### **Limitations of the Study**

1. Variations in meteorological status like mat condition, room lightening, atmospheric temperature, humidity etc., which may effects the execution of techniques during the collection of data, and it could not be controlled.
2. Individual differences in body morphology, flexibility, and other factors that can influence the execution of judo techniques. These variations can impact the generalizability of findings.

3. Biomechanical analyses often involve static or dynamic conditions, while judo techniques occur in dynamic and rapidly changing situations. Capturing the dynamic nature of judo movements can be challenging.
4. The effect of uncontrollable factors such as sudden emotional disturbance of the subjects due to factors other than related to sports was considered as the limitation of the study.
5. Biomechanical studies are often conducted in controlled laboratory settings, which may not fully replicate the dynamic and unpredictable nature of actual judo competitions. The ecological validity of findings is to be limited.

### **Hypotheses of the Study**

In this study aim to undergone a biomechanical analysis of selected judo techniques across different weight categories, focusing on kinematic interpretations during execution. Hence the following research hypothesis has been formulated.

- H<sub>1</sub>: The Weight Categories has significant influences on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships.
- H<sub>2</sub>: The selected Judo Techniques has significant influences on kinematic variables with respect to the weight categories in the execution of selected judo techniques at the All-India Interuniversity level judo championships.
- H<sub>3</sub>: There is a significant interaction between Weight Categories and Judo Techniques on Kinematic Variables in the execution of selected judo techniques at All-India Interuniversity level judo championships.

## Definitions and Explanations of the Terms

### 1. **Mechanics**

“The branch of physics deals with the motions of material bodies. Mechanics is the area of mathematics and physics concerned with the motions of physical objects, more specifically the relationships among force, matter, and motion. Forces applied to objects result in displacements, or changes of an object's position relative to its environment”.

**Saunders Comprehensive Veterinary Dictionary, 3 ed. © 2007 Elsevier**

### 2. **Angular Velocity**

“Change in the Angular displacement during a given period of time in physics, angular velocity or rotational velocity, also known as angular frequency vector, is a vector measure of rotation rate, that refers to how fast an object rotates or revolves relative to another point, i.e. how fast the angular position or orientation of an object changes with time”.

**Wikipedia**

### 3. **Angular Displacement**

“In an angular motion, the shortest angle between the start and finish points of an object. It is the angle in radians, degrees or revolutions through which a point revolves around a center or a specified axis in a specified sense. When a body rotates about its axis, the motion cannot simply be analyzed as a particle, as in circular motion it undergoes a changing velocity and acceleration at any time (t)”.

**Wikipedia**

### 4. **Angular Distance**

It is measured as the sum of all angular changes undergone by a rotating body.

**Susan J.Hall**

## 5. **Radian**

A radian is defined as the size of the angle subtended at the center of a circle by an arc equal in length to the radius of the circle.

**Susan J . Hall**

## 6. **Speed of Movement**

“A Scalar measure of the rate of movement of a body expressed either as the distance travelled divided by the time taken (average speed) or the rate of change of position with respect to time at a particular point (instantaneous speed). It is measured in metres per second, miles per hour”, etc.

**Wikipedia**

## 7. **Height of CoG**

“The length between a point around which a body’s weight attracted by the center of earth and the surface of the floor. The center of gravity (CoG) of an erect person with arms at the side is at approximately 56% of the person's height measured from the soles of the feet. The center of gravity shifts as the person moves and bends. The act of balancing requires maintenance of the center of gravity above the feet”.

**Wikipedia**

## 8. **Mechanical Advantage**

“It is the ratio of force arm to the resistance arm. Mechanical advantage is a measure of the force amplification achieved by using a tool, mechanical device or machine system. The device trades off input forces against movement to obtain a desired amplification in the output force”.

**Wikipedia**

9. **Judoka**

“A judo practitioner or an athlete who practices judo”

**Kodokan Dictionary**

10. **Uke**

“Uke is in Japanese martial arts the person who "receives" a technique. An uke typically partners with a partner or nominal opponent”

**Kodokan Dictionary**

11. **Tori**

“Tori is a term used in Japanese martial arts to refer to the executor of a technique in partnered practice”.

**Kodokan Dictionary**

12. **Movement Time**

“Movement time is defined as the time taken to complete a discreet, predefined motor task.”

**Encyclopedia of Movement Disorders,**

13. **Angle of Hip Flexion (Hip Angle)**

The angle of hip flexion was defined as the angle between the left acromion process to the great trochanter and the left great trochanter to the knee.

**(Glassbrook et al., 2017)**

14. **Angle of knee Flexion (Knee Angle)**

The angle of knee flexion was defined as the angle between the anterior superior iliac spine to the center of the patella and from the center of the patella to the tibial tuberosity.

**(Science Direct)**

### **Significance of the Study**

1. The research could be useful in determining the prevalence of certain kinematic variables in specific judo techniques.
2. The research could be useful in determining the kinematic precedence of the selected judo techniques.
3. The research could be useful in determining the differences in kinematic properties of various judo techniques in respect to body weight.
4. The research could be useful in documenting the mechanical benefits of the selected judo techniques.
5. The study's findings may aid judokas in improving their own technical excellence when practicing judo techniques.
6. The findings of the study may aid judokas in selecting a judo technique which is more kinematical advantageous for their weight category.
7. This information can be used to refine and optimize techniques for efficiency and effectiveness.
8. The results of the technical analysis can contribute to a deeper understanding of the tactical aspects of judo.
9. By examining the biomechanics of different techniques, researchers can identify strategic advantages and limitations, helping athletes make more informed decisions during competitions.
10. It bridges the gap between theoretical knowledge and practical application in the training environment.

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Chapter II

**REVIEW OF THE RELATED LITERATURE**

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Studies on Application of Biomechanical Analysis in Judo .....	49
Studies on Biomechanical Analysis of Combat Sports .....	64
Studies on Biomechanics in the Field of Sports.....	69

The researcher has long gone through the numerous literatures within the discipline of biomechanics and the mechanical analysis, out of which the researcher had long gone through a few kinematical parameters. The researcher visited many locations wherein the studies literature can also additionally be available. The researcher attempted to study many literatures which turned out to be useful to the study. The associated literature helped to find applicable locations, which allows the researcher to cite the studies research from the reviewed literature.

### **Studies on Application of Biomechanical Analysis in Judo**

**Hassan Soror Aboelwafa (2021)** had done a study on Kinematics characteristics of Seoi-Nage and reverse skill in judo. This study aims to identify the kinematic characteristics of performing traditional SeoiNage and developed Seoi-Nage (reverse skill). To compare both methods, 10 athletes with a high-performance level of both skill were chosen from the Egyptian youth national team to perform both method. The data were collected using a three-dimensional coordinate setup with 4 cameras recording at the speed of 250 frames/s; motion analysis, using a semi-motion system, was used to analyse the attacking athlete's performance. The obtained results allowed to identify the kinematic characteristics of both methods and differences between them (e.g., motion phase time, motion phase displacement, motion phase velocity, motion phase acceleration) that were in favour of reverse Seoi-Nage in most kinematic variables during the three phases of performance. The obtained results suggest that trainers should teach the traditional skill to young athletes first and then teach the reverse skill based on the principle of gradual transition from easy to difficult in the process of education and training. Training of high level athletes in judo on the reverse skill is performed owing to its great effectiveness during matches compared

to the traditional skill. The objective of the study is to find out the fundamental differences in the way the performance of each of the two skills, the results showed a clear superiority of the reverse skill in the performance of the three stages Kinematics Characteristics. Through the results of this research, Training beginners on the traditional seoi-nage first and then the reverse seoi-nage in accordance with the principle of gradual easy to difficult, Training of high level players in judo on the reverse skill because of their great effectiveness during matches compared to traditional skill, design the special physical exercises that increase the efficiency of movement of body members that have a key role during performance, especially for high levels, More scientific research on the skills of throwing developed from the creations of high levels players, the results of this research can help coaches to training program development and achieve greater results in competitions.

**Haruo Murayama, Masahito Hitosugi, Yasuki Motozawa et.al (2020)** had done Biomechanical Analysis of the Head Movements of a Person Thrown by the Judo Technique 'Seoi-nage'. The present study examined the kinematics and biomechanical parameters of the head of a person thrown forward by the judo technique 'Seoi-nage'. A judo expert threw an anthropomorphic test device (the POLAR dummy) five times. Kinematics data were obtained with a high-speed digital video camera. Linear and angular accelerations of the head were measured by accelerometers mounted at the center of gravity of the dummy's head. When Seoi-nage was performed, the dummy fell forward accompanied by contacting the anterior parietal regions of the head to the tatami, and the linear and angular accelerations of most axes reached peak values when the head contacted the tatami. Peak resultant linear and angular accelerations were  $20.3 \pm 9.8$  G and  $1890.1 \pm 1151.9$  rad/s<sup>2</sup>, respectively (means  $\pm$  standard deviation). Peak values in linear and angular acceleration did not significantly differ between the three directional axes. Absolute angular accelerations in all axes observed in Seoi-nage were high and the resultant value was approximately equal to the already reported in Ouchi-gari, one of the predominant techniques causing judo-related acute subdural hematoma. However, the remarkable increase of linear acceleration in the longitudinal direction and/or angular acceleration in the sagittal plane, as previously reported in techniques being thrown

backward (i.e., Ouchi-gari and Osoto-gari), was not detected. The likely mechanism of acute subdural hematoma caused by Seoi-nage is that a large angular acceleration causes large strains and deformations of the brain surface and subsequent rupture of cortical vessels.

**Dany Alexis Sobarzo Soto, Esteban Aedo-Muñoz, Ciro José Brito, et.al. (2020)** had done a Comparisons of Motor Actions and Biomechanical Assessments of Judo Techniques Between Female Weight Categories. This study aimed to perform motor action and biomechanical analysis of techniques in female judo athletes separated by weight categories of 638 female bouts (103 extra lightweight <48 kg, 140 half lightweight 48>52 kg, 65 lightweight 52>57 kg, 73 half middleweight 57>63 kg, 77 middleweight 63>70 kg, 80 half heavyweight 70>78 kg and 60 heavyweight >78 kg). All bouts were analyzed following the phases of approach, gripping, defensive action, attack, also biomechanical analysis of techniques and groundwork was performed ( $p \leq .05$ ). Results indicated that lightweight athletes presented lower attempts to grip, right collar grip and left collar grip frequencies than other categories. Extra lightweight judokas presented lower right back grip and left back and sleeve grip frequencies as well as lower occurrence of techniques with arm and leg lever scored than half lightweight athletes, while half lightweight athletes demonstrated higher frequency of techniques with waist lever variable scored than lightweight ones. These findings should be considered for training prescription.

**Yukinori Yamamoto, Norihisa Fujii and Sekiya Koike (2019)** had done a biomechanical study of seoi-nage in judo influence of elbow's pain on motion. The aim of this study is to clarify Seoi-nage technique for reducing injuries in elbow joints. Uchikomi and Nagekomi were used as the trials. Two judo athletes with pain in elbow and three athletes without pain in elbow were instructed to perform the Seoi-nage as Tori. Five male college Judoka (Height:  $169.2 \pm 5.5$ cm, Mass:  $74.2 \pm 7.9$ kg, Age:  $21.8 \pm 3.3$ y) volunteered as participants, one as the Uke (receiver) and the others five as Tori (Thrower). Two of Tori have pain in the elbow and the other three do not have pain. One top Judoka without pain, got World champion. Participants were instructed to perform two practice skill of Seoi-nage, Uchikomi (Not throw) and the Nagekomi

(Throw). Strain gauge sensors were set in a judo cloth to measure the force applied by Tsurite (hand grasping the Eri). Uchikomi and Nagekomi, practice skills for Seoi-nage, were used in the experimental trials. Ninety-four and two reflective markers were attached to the participants and the sensors, respectively. Three-dimensional coordinate data of the markers were obtained by a motion capture system (VICON-MX, Vicon Motion Systems, 14 cameras, 250Hz.). The results were observed as the follows: i) The athletes without pain applied a large force towards the throwing direction by the internal-rotation of shoulder. ii) In athlete with pain, the force direction was not towards throwing direction, but towards the left rotating side. The group without pain had an ideal movement of applying Seoi-nage. On the other hand, the group with pain did not apply kuzushi, but generate force to throw the Uke by putting flexing the trunk with external-rotation position of the shoulder. The way of applying the technique changes due to the characters of Tori's body, which should be considered individually in order to reduce the injuries.

**Deepak Dhaka, Reena Hooda (2019)** conducted a study on Implementing Biomechanics to Study Motions of Judokas through Kinovea Software for Enhancing their Performance & Maintaining Center of Gravity during Throwing Techniques. Judo is world famous game and art of hand-to-hand combating with peaceful mind. There are different techniques of Judo which include different motions of legs & knees, arms, trunks and head to generate required force to perform a technique effectively. Some techniques involve maximum use of limbs when other requires perfect use of head, trunk and limbs in locomotion of Judokas during competition. The winning is dependent on how perfectly the Tori (attacker) applied combination of his muscles power to lift up lever at right position, generate required force to be concentrated on focus to displace the Uke(defender.) Applicability of Biomechanics turned the Judo art into more scientific game that assist in describing the required force by each body motion during fighting. Biomechanical appliances on tradition Judo helps in improving the traditional methods, performing more logically and accurately. The current paper just focus on the throwing techniques of Judo in which whole parts of the Tori 's body work in together to off-balance the Uke's body. The paper highlights how body parts act as lever to shift the maximum force at a particular

point while maintaining the center of gravity in throwing the Uke's body without misbalancing itself, avoiding injuries in head, backbone & its lower part near sacrum. Kinovea software is used to study the locomotion of Judokas at different points, track the speed & distance of body motions and path traced during practice that is discussed in the paper.

**Takanori Ishii, Michiyoshi Ae and Yuta Suzuki et.al (2018)** had done a kinematic comparison of the seoi-nage judo technique between elite and college athletes. By comparing kinematics of elite and college judo competitors, this study intended to find biomechanical characteristics that determine fast and skilled execution of the seoi-nage (shoulder throw) technique. Three-dimensional motion data were collected when three male elite and seven male collegiate judo competitors practised seoi-nage using a VICON-MX system with 18 cameras running at 250 Hz. There was no significant difference in motion phase time of the turning phase between the two groups, indicating that motion phase time is not always a factor contributing to seoi-nage quickness. During the turning phase, the maximum relative velocity of the whole body centre of mass along the anterior-posterior direction was substantially greater in elite athletes (2.74 0.33 m/s) than in collegiate athletes (1.62 0.47 m/s) ( $p = 0.023$ ). In top athletes, the overall angular velocity of body part lines, notably the arm line, tended to be larger ( $p = 0.068$ ). The findings imply that the thrower's velocity compared to the opponent during the forward drive and turning motion represents high skill seoi-nage. When teaching the judo throw technique, coaches should recognise relative forward velocity as a component that may lead to a successful seoi-nage.

**Takanori Ishii and Michiyoshi Ae (2014)** The purpose of this study was to compare the seoi-nage techniques between the elite and non-elite judo athletes. The information obtained helps to increase our knowledge on biomechanical factors to determine the effectiveness of seoi-nage. The motion data of the seoi-nage were collected on three male elite judo athletes and seven male student athletes using a three-dimensional motion analysis technique. The velocity generated by the hikite and hip were greater and the angles of pulling and hitting were smaller in the elite judo athletes than the student judo athletes. The comparison of the effects of the velocity

and angles of pulling and hitting on the generation of the angular momentum of uke implied that these variables could be indices for coaches to evaluate the effectiveness of the seoi-nage. In judo, an athlete grips an opponent's "gi", traditional and special clothes used for judo practice and competition, with hands and pulls or pushes the opponent to lose his/her balance (Kuzushi) and to generate appropriate conditions (Tsukuri and Kake) for a successful throw. Some specific movements are required for a quality nage-waza, which is a challenging task for all judo-kas. The judo-kas needs to move the opponent into an appropriate position by the effective use of opponents' own power (Matsumoto, 1975). Seoi-nage is one of the most frequently used technique in judo matches by both elite and non-elite judo athletes. The seoi-nage is accomplished by pulling an opponent forward to lose his/her balance, then pick up the body on the back and throw over the shoulder. Recent statistics analysis done by the judo laboratory in the University of Tsukuba, Japan, on the matches of the London olympic games (2012) showed that 54.7% of the matches were won by the nage-waza, followed by penalty (21.7%), the katame-waza (16.5%), and judgment (6.3%), and approximately 20 % of matches determined by the nage-waza were occupied by the seoi-nage. This reveals that the improvement in the seoi-nage technique enhances the judo performance. Many coaches usually evaluate and give advices to athletes in the technique training, based on coaches' observation and their experience with less scientific evidence. However, we need to find quantitative criteria to evaluate the level of the seoi-nage technique by investigating biomechanical differences in the seoi-nage technique between elite and non-elite judo athletes. Therefore, the purpose of this study was to compare the seoi-nage techniques between the elite and non-elite judo athletes. The information obtained helps to increase our knowledge on biomechanical factors to determine the effectiveness of seoi-nage.

**Sentaro Koshida, Takanori Ishii, Tadamitsu Matsuda and Toshihiko Hashimoto (2014)** were done a study on Biomechanics of the judo backward breakfall: comparison between experienced and novice judokas. Head injuries sustained during the sport of judo have gained significant public attention because of the incidence of severe cases among novice judokas in Japan. The judo backward breakfall skill may play an important role in decreasing the number of head injuries.

Therefore, more effective ways to acquire appropriate judo backward breakfall skills are needed, and this requires a greater understanding of the breakfall movement. The aim of the study was to investigate the kinematics and muscle activation patterns during a judo backward breakfall in experienced and novice judokas. Eleven experienced judokas and 13 novice judo judokas volunteered for the study. Three-dimensional kinematic data were collected while participants performed five sets of backward breakfalls. We documented head, neck-, trunk-, hip and knee-angle time profiles and electromyographic activities of the sternocleidomastoid, external oblique and rectus abdominis muscles during breakfalls. We found significant difference in the knee joint motion during the judo backward breakfall between the experienced and novice judokas. However, there were no significant differences in the activation patterns of any muscles between the experienced and novice judokas. In addition, the timing of hand impact appeared to coincide with the timing of peak head linear acceleration. The knee joint movement and the hand impact skill may be important components of the judo backward breakfall motion.

**Rodney Imamura, Benjamin Johnson (2013)** had done A kinematic analysis of a judo leg sweep: major outer leg reap-Osoto-gari, Twenty male judo players (10 black belt; 10 novice) executed the major outer leg reap, osoto-gari, with maximal effort. Each throw was recorded within the two-dimensional sagittal plane using a 60 Hz video camera. Kinematic data that best described the power of the 'tori's' (thrower's) sweeping leg and the velocity of the 'uke's' (recipient's) falling body were analysed using a Peak Performance Technologies Inc. Motus system. Data from black belt and novice groups were statistically analysed using a one-way MANOVA ( $p = .05$ ). Statistical analysis found only two variables for the 'tori' (peak angular velocity of the trunk; TTRK, and peak angular velocity of the ankle; TANK) to be significantly different. Large TTRK values for the black belt group indicated a proficient ability to create large momentum on the upper body of the 'uke'. Significantly larger differences in trunk rotation velocities of the 'uke' by the black belt group reinforced this notion. These differences were attributed to good upper body to upper body contact or impact, which is considered an important aspect of the 'osoto-gari'. Significant differences in TANK values stressed the importance of executing plantar flexion near sweep contact.

The results emphasized the importance of using the sweeping leg in a sequential kinetic link motion rather than as a single rigid segment.

**Franchini, Emerson and Artioli, Guilherme and Brito, Ciro (2013)** The understanding of time-motion and physiological responses to judo combat is important to training organization. The keywords "judo and competition," "judo and physiology," "judo and randori," "judo and time-motion analysis," "judo and combat," "judo and match," and "judo and biochemistry" were used to generate the review's results. During judo bouts, the effort-pause ratio is between 2:1 and 3:1, with 20–30 second effort intervals and 10 second breaks. As a result, all three metabolisms are involved in judo combats: the aerobic system handles the recovery processes between high-intensity actions and matches, the anaerobic lactic system maintains high-intensity actions for longer periods of time (such as grip disputes), and the anaerobic lactic system is in charge of the short-duration powerful actions during technique applications. These needs must be taken into account when designing a training program, and a muscle-specific action analysis can help determine the best course of action for enhancing judo athletes' performance. During technique executions, the lower body often performs short-term, high-intensity activities, whereas the upper body's muscular groups perform both strength-endurance and power actions. Judo is known for its high cardiovascular demand because to the several muscle groups that are used in various motions during the fight.

**Sebastiao and Saray Giovana dos Santos (2012)** conducted a study on influence on height when using in seoi nage. Judo techniques use the assumption of maximum efficiency with minimum energy expenditure, which means to try to use the strength of the opponent against himself, causing an imbalance that, associated with a technique, helps execute a throw. This study is aimed to evaluate the mechanical efficiency of the seoi nage technique applied to judokas (uke) of different heights in relation to the thrower (tori). The knee and trunk angular variation of tori was compared with the total throw time, the time to perform each phase of the technique, and the behavior and vertical variation of the trajectory of tori's center of mass ( $\Delta$ CM). Ten throws using the seoi nage technique on three uke of shorter,

equivalent, and taller statures compared to tori were cinematically analyzed. The images were recorded at 180 Hz using the Peak Motus System. The data was analyzed by descriptive statistics, ANOVA, and Tukey's post-hoc ( $p < 0.05$ ). The tori's mechanical efficiency was greater when throwing a uke of a stature taller or of his same height, while the total throw time was shorter for a taller uke. The  $\Delta$ CM of the tori was greater to throw a uke of a shorter stature. The conclusion is that the seoi nage technique is most effective when applied against opponents of heights equal to or taller than the tori.

**Sebastião Iberes Lopes Melo, Saray Giovana dos Santos (2011) et.al** done a study on the biomechanical efficiency of judo throw techniques depends on the anthropometric characteristics of the opponent. This study aimed to evaluate the mechanical efficiency of the o soto gari technique when applied to judoists of different heights in relation to the thrower. Material/Methods: The following factors were compared: the tori angular variation of knee, hip and trunk; the total and partial performance time and the displacement of the vertical trajectory of the tori center of mass (DCM). Three uke of shorter, similar and taller stature than the tori were kinematically analyzed performing ten o soto gari throws. The images were recorded at 180 Hz using the Peak Motus System 3D. The data were analyzed by descriptive statistics, ANOVA and post-hoc Tukey ( $p \leq 0.05$ ). Results: The mechanical efficiency of angular displacement was greater when the tori was throwing shorter uke; the throwing time was shorter against shorter uke; the tori DCM was greater when throwing shorter uke. Conclusions: We conclude that the o soto gari technique is more efficient when applied to shorter opponents.

**Kab-Sun Kim Chuel-Hong Park, El-Koo Lee et.al (2011)** had conducted a Kinematic Analysis of Harai-Goshi(Hip Throw) in Judo. The purpose of this study was to perform a kinematic analysis of Harai-goshi(hip throw) in superior female judo players. From our analysis, it appeared desirable for the player to shorten the duration of the technique for maximum results. It was also desirable for the player to draw the opponent backward while simultaneously maneuvering her close to her own body. A turning movement of the body toward the left side was found to be required for the

technique, during which the player must lower the position of the center of gravity. During the subsequent angular change of the elbow, the player winds the elbow and, by moving the left shoulder, pulls the opponent toward her. The player lowers the body center by bending the left knee and letting the right knee extend, while turning the upper body and bending the hip joint. The player then draws the opponent in, contacts the opponent closely, turns, and stretches the right knee and hip joint rapidly and concisely, completing the move; it was also found to be desirable for the angular velocity to be increased for maximum efficacy.

**Michaela Hassmann, Michael Buchegger (2010) et.al** had done a study on Motion analysis of performance tests using a pulling force device simulating a judo throw .A pulling force device is used to carry out monthly performance tests on 12 judo athletes of the Olympic Center Linz, Austria.The variation of a friction brake simulates the resistance of the opponent in the throwing technique Seoi-Nage. By measuring force and velocity, the parameters  $F_{max}$ ,  $t(F_{max})$ ,  $dF_{max}$  and  $v_{max}$  are calculated using LabView. A synchronous 3D motion analysis in Peak Motus shows the quality of movement in more detail. The relevant investigations comprise the 3D position of center of mass, ankle and shoulder; knee and elbow angle, body axis as well as trunk rotation. The PFD used for the investigations in this paper is described in [13]. It consists of a chain decelerated by the variable resistance of a friction break calculated basing on formula (1), simulating the resistance of the opponent.Data acquisition of a force and a velocity sensor with a frequency of 1000 Hz, processing and analysis are done in LabView 8.5. A 2x 2D motion analysis in Dartfish films the motion of the athlete with one camera view from one side and one from above. For synchronisation an LED is used, showing up in one camera view when DAQ starts, the event from where the videos are cut using Dartfish. Displaying force and velocity curves together with the two recorded videos in a LabView GUI provides a useful and helpful visualization and feedback for athletes and trainer. The cross-sectional analysis of the six test series so far compares among the squad by standardization by weight categories. The longitudinal analysis shows improvements in judo-specific abilities according to the training periods to check the effectiveness of training measures. The 3D motion analysis provides more detailed information about

variations of technical performance, imperfections and mistakes. All results are compared to findings in literature if existing, but the comparability to the trajectories were limited as only the first two throw phases were recorded. In addition, they were drawn by hand and not calculated by software. The trunk rotation has never been displayed in this way before.

**Attilio Sacripanti (2010)** had done a study on the Biomechanics of Kuzushi-Tsukuri and Interaction in Competition. In this paper it is performed the comparative biomechanical analysis of the Kuzushi (Unbalance) – Tsukuri (the entry and proper fitting of Tori’s body into the position taken just before throwing) phases of Judo Throwing techniques. The whole effective movement is without separation, as already stated by old Japanese biomechanical studies (1972 -1978), only one skilled connected action, but the biomechanical analysis is able to separate the whole in didactic steps called Action Invariants. The first important finding singled out is the existence of two classes of Action Invariants the first the General one’ connected to the whole body motion is specific of shortening distance in the Kuzushi Tsukuri Phase. The second one, the Specific Action Invariants is connected to the superior and inferior kinetic chains motion and right positioning connected both to Kuzushi and Tsukuri phases. Some interesting findings derive from this analysis: among throwing techniques, couple techniques could be independent from Kuzushi; instead physical lever groups need all two action invariants to be performed successfully and as complex motor skill they are more difficult to perform than the first ones. Complexity in motion is connected to the energy consumption, and to the skill ability of athletes. This biomechanical comparative analysis is useful from the didactic point of view, clarifying the basic mechanical steps of all throws, and showing also hidden connections, similarities and differences among throwing Judo techniques. The last part of the paper concerns the study on Interaction in Competition, performed by the author, showing 20 years results on Judo Biomechanics.

**Rodney T. Imamura, Misaki Iteya, and Rafael F. Escamilla (2007)** had conducted A kinematic comparison of the judo throw *Harai-goshi* during competitive and non-competitive conditions. The purpose of this study was to compare the

kinematics of kuzushi/tsukuri (KT) phases of the harai-goshi throw under competitive and non-competitive conditions. A third degree black belt subject served as the tori (thrower) for both conditions. Two black belt participants ranked as first degree and fourth degree served as the uke (faller) for the competitive and non-competitive conditions, respectively. Two video cameras (JVC 60 Hz) and a three dimensional motion analysis system (Vicon-Peak Performance Technologies, Inc., Englewood, CO) were used to collect and analyze peak velocity for the center of mass (COM) of uke and tori and peak angular velocity of tori's trunk (TAV). Data were smoothed using a 4th order zero lag Butterworth filter with a cut-off frequency set by the Peak software optimization technique. All variables were normalized by time as a percentage of the KT phase. In general, the COM directional velocity patterns were similar between conditions. Uke's defensive efforts during the competitive condition created differences in timing and magnitude of peak COM and TAV velocities. During competition, tori created larger peak COM velocities onto uke which indicated greater throwing power. Peak velocities for tori's COM were larger during the non-competitive condition since uke's resistance was minimal. Findings of the competitive condition suggested that mediolateral COM movement towards tori's pulling (left) hand can be an ideal set-up movement prior to execution. Tori's TAV was also greater during the competitive condition. Two distinct TAVs were observed, a counterclockwise TAV created by tori turning their hips during the entrance of the throw and a clockwise TAV created by the shoulders turning to complete the 180 degree body turn with the simultaneous leg sweep. It is thought that the counterclockwise rotation aids in producing a pre-stretch of trunk muscles which helps to create greater trunk rotation power.

**Imamura, Hreljac, Escamilla and Edwards (2006)** A three-dimensional analysis of the center of mass for three different judo throwing techniques. Four black belt throwers (tori) and one black belt faller (uke) were filmed and analyzed in three-dimensions using two video cameras (JVC 60 Hz) and motion analysis software. Average linear momentum in the anteroposterior (x), vertical (y), and mediolateral (z) directions and average resultant impulse of uke's center of mass (COM) were investigated for three different throwing techniques; harai-goshi (hip throw), seoi-

nage (hand throw), and osoto-gari (leg throw). Each throw was broken down into three main phases; kuzushi (balance breaking), tsukuri (fit-in), and kake (throw). For the harai-goshi and osoto-gari throws, impulse measurements were the largest within kuzushi and tsukuri phases (where collision between tori and uke predominantly occurs). Both throws indicated an importance for tori to create large momentum prior to contact with uke. The seoi-nage throw demonstrated the lowest impulse and maintained forward momentum on the body of uke throughout the entire throw. The harai-goshi and osoto-gari are considered power throws well-suited for large and strong judo players. The seoi-nage throw is considered more technical and is considered well-suited for shorter players with good agility. A form of resistance by uke was found during the kuzushi phase for all throws. The resistance which can be initiated by tori's push or pull allows for the tsukuri phase to occur properly by freezing uke for a good fit-in. Strategies for initiating an effective resistance include initiating movement of uke so that their COM is shifted to their left (for right handed throw) by incorporating an instantaneous "snap pull" with the pulling hand during kuzushi to create an opposite movement from uke. The results also indicated an importance for large momenta being generated for this throw, particularly in the anteroposterior and mediolateral directions. The average resultant impulse for osoto-gari was similar to that of harai-goshi indicating the importance of a strong collision between tori and uke. Since osoto-gari does not require a 180 degree turn of tori's body, it is often considered an easier throw to execute. From this perspective it is well suited for players with limited mobility skills and heavy players who can generate large momentum before contact.

**M. Pucsek, K. Nelson, and E.D. Ng (2005)** had done a kinetic and kinematic analysis of the Harai-goshi judo technique. The purpose of this study was to analyze and compare the kinetic and kinematic characteristics of the throwing technique, Harai-goshi of novice and advanced judo competitors. A heterogeneous group of 28 male and female judo competitors participated in this study. Each subject was required to perform three successful trials. Kinetic and kinematic data were collected by utilizing the Kistler Instrument Corporation Multicomponent Force Measuring Platform System and the Peak Technologies Motion Video Analysis System. Data

were collected in order to quantitatively and qualitatively analyze the horizontal and vertical forces of the support leg, and the horizontal and vertical velocities of the sweeping leg during execution of the throwing technique, Harai-goshi (hip sweep). The study revealed a significant difference in horizontal force application, between novice and advanced judo competitors. In addition, we found numerous significant relationships among mean horizontal ground reaction force application and horizontal leg sweep velocity in 19 of the 28 participants when analyzed individually. The results suggest (1) leg sweep velocity is a function of ground reaction force application; and (2) horizontal leg sweep velocity plays a primary role in good technical execution of the Harai-goshi throw.

**Kim, Eui-Hwan Kwon, Moon-Seok, (2002)** done a kinematic analysis of uchi-mata (inner thigh reaping throw) by kumi-kata types and Two opponents' different height in judo. The purpose of this study was to analyze the kinematic variables when Uchi-mata(inner thigh reaping throw) performing by Kumi-kata(engagement positioning, basic hold) types A, B(A: grasping part-behind neck lapel, B: chest lapel) and two opponents' different heights in Judo with three dimensional analysis technique DLT method by videography. The subjects were four male judokas who have been training in Yong-In University(YIU), on Korean Representative level and Uchi-mata is their Tokuinage (favorite technique), the throwing form was filmed on two S-VHS 16mm video camera ( 30frame/sec. Panasonic). The first, Kinematic variables were temporal, posture, and COG that The mean values and the standard deviation for each variable were obtained and used as basic factors for examining characteristics of Uchi-mata by Kumi-kata types. The data collection was performing by Uchi-mata. Six good trials were collected for each condition (type A, B) among over 10 trials. The mean values and the standard deviation for each variable were obtained and used as basic factors for examining characteristics of Uchi-mata by Kumi-kata types. Kinematic variables were temporal, posture. The second, Data analysis was collective comparison of two-way ANOVA, t-test by type AB and two opponents' different heights. The study suggested that that Judoka hold on the partbehind neck lapel(type A) at the sleeve with the other of Judogi jacket when opponents' height was short. Because the time elapsed on KP of type B

was not so fast as type A ( $p < .05$ ) during performed Uchi-mata, and also the bigger hip-angle of the supporting foot in the 2nd stage of KP grew, the faster the time elapsed on KP became.

**Matthew Exton and Yoshihiko Iursa (1991)** had conducted a biomechanical study on tomoe-nage of judo techniques. The investigation combined the use of cinematography and dynamography to determine the consistency of performance of skilled Judokas and the differences in throwing technique. This involved filming a number of Judo throws and comparing the filmed motions with the dynamographic traces. From the result, author found allied peaks and troughs of the traces with fundamental points of the analyzed throws and concluded that different Judokas may use different styles of performance for the same throwing techniques. The objective of this study was to obtain further information on a Judo throw and its mechanical principles, analyzing normal and competitive throws of Tomoe-Nage with quantitative manner. Synchronization of the recorded and cinematographic data was overcome by using Signal generator producing pulses at 64Hz, the same frequency as the camera speed. The Signal generator attached to the boom, a channel of the recorder, and also to a light bulb. This light bulb was placed within view of the camera to interlink the two sets of data by visually marking the point on the film at which the synchronizing of the data may be taken. Analysis of the cinematographic result was carried out on a film motion analyzer. The segmental mass and center of gravity values were taken from Dempster's (1955a) data, the segmental moment of inertia was taken from that of Whitsett (1963). To obtain cinematographic data in conjunction with the piezoelectric data, the sequence was analyzed from the first frame in which the light from the Signal generator was seen to be lit. Analysis of the piezoelectric accelerometer results'; was carried out with the use of the recorder connected to a graph plotter via a signal analyzer. The results were recorded from the point at which the first signal from the fourth channel as the Signal generator recording was received when it was triggered. The above was repeated for all three channels and for each required throw. Tomoe-nage of Judo throw and its mechanical principles was investigated in this study comparing the normal with competitive throw with 3 Ukes differing mass. And analysis of center of gravity, moment of inertia, angular velocity,

and angular momentum during the motion of Tomoe-nage with piezoelectric accelerometer resulted as follows. The displacement of center of gravity for 3 Ukes during the normal throw showed similar tendency. The moment of inertia for Light and Middle-Weight Ukes showed similar tendency but those in Heavy-Weight Uke showed difference during the normal throw. And its maximum values supported the theory that the moment of inertia is proportion to the mass. The angular velocity for 3 Ukes during the normal throw showed similar curve consist of several peaks and troughs but the phase and magnitude of each curve showed difference. The value of the angular momentum for Tori during the normal throw showed the minimum at the stage of "Tukuri" and the maximum at the stage of "Kake" In the comparison of the angular velocity for Middle-Weight Uke during the normal and competitive throw the latter showed greater change of gradient and decrease in the time taken to throw the Uke. In the comparison of the piezoelectric traces for Middle-Weight Uke during the normal and competitive throw a similar tendency was shown. But the difference in the time between pulling Uke and bend leg for lifting Uke was observed.

### **Studies on Biomechanical Analysis of Combat Sports**

**Daichi Yamashita, Hiroshi Arakawa, et.al (2020 )** had done a study on the Whole-Body Mechanics of Double-Leg Attack in Elite and Non-elite Male Freestyle Wrestlers. This study examined the movement characteristics of the double-leg attack in elite and non-elite wrestlers. Twenty light-weight male wrestlers were divided by skill level: Elite group (n = 11) who participated in international-level competitions and Non-Elite group (n = 9) consisting of college-level wrestlers. Each wrestler performed the double-leg attacks against a defender. Three-dimensional coordinates of anatomical landmarks and the ground reaction force (GRF) of the trailing limb were analyzed. The forward velocity and displacement of the whole-body center of mass (COM) and the 7th cervical spine (C7), which represents the upper body, were calculated. Additionally, joint torques were calculated by a standard inverse dynamics method. No significant differences were observed between groups for movement duration and the C7 forward displacement, which relates to the interpersonal distance. Still, they were significantly correlated in the non-elite wrestlers, as well as in all

wrestlers ( $r = 0.78$ ,  $p < 0.05$  and  $r = 0.65$ ,  $p < 0.01$ , respectively). While there were no group differences in joint angles at both limbs and torques at the trailing limb, the time-to-peak resultant GRF was shorter, and peak resultant GRF was greater at the trailing limb in the elite wrestlers compared to that in the non-elite wrestlers ( $p < 0.05$ ). There were no group differences in peak forward velocity of the COM and the C7. However, the C7 forward velocity at 0.20, 0.25, and 0.30 s and the C7 forward displacement at 0.35 s after the start of the attack was significantly greater in the elite wrestlers compared to that in the non-elite wrestlers ( $p < 0.05$ ). This disparity in the C7 forward velocity made a positive contribution in forward displacement by 0.08 m at 0.35 s. Thus, during a double-leg attack, elite wrestlers quickly move their upper body forward while rapidly pushing-off the trailing foot reaching the defender's legs in advance of defensive actions, irrespective of the interpersonal distance. These characteristics may improve the success rate of the double-leg attack.

**Moufti H. and Arfaoui (2019)** had done a Kinematic analysis of the “attack to the legs” from wrestling: impact of prior judo expertise, In the framework of motor skill learning and transfer, the objective of the present work is to highlight the kinematics during the technical execution of an “attack to the legs” in wrestling and compare expert wrestlers with wrestlers having a prior judo expertise. Moreover, this study aims to evaluate the effects of training on these characteristics. 10 male subjects were divided in two groups of five: the first group contains wrestlers with at least 7 years of wrestling practice. The second group contains two-year practice wrestlers with 5-year prior judo experience. Subjects had to perform a movement of attack towards the opponent’s legs (free style wrestling). A three dimensional analysis was carried, the displacement of seven passive markers placed over anatomical points was quantified (3-D motion analyzer, sampling rate 25Hz). The following parameters were calculated: angulation of the hip and of the knee, velocity and acceleration of the shoulder and of the wrist. The experiment was conducted twice: at the beginning of the wrestling training schedule and ten weeks later. Results showed marked differences between the two groups in the kinematics of the movement. These results suggest interference between prior automatisms and learning new skill. The prior experience in judo would have influenced posture in this group. In the framework of

skill transfer and dexterity, this study appears promising to investigate the processes involved in this motor control. Although wrestling and judo are two sport disciplines that belong to the same group of combat sport, this work underlines the specificity of learning and indicates that acquisition of motor abilities in a specialty is not transferred inevitably in a positive way in another specialty of the same group.

**Krzysztof Buśko, Pantelis T. Nikolaidis (2018)** had done a study on Biomechanical characteristics of Taekwondo athletes: kicks and punches vs. laboratory tests. The aim of the study was to examine biomechanical characteristics of taekwondo athletes comparing kicks and punches with laboratory tests of muscle strength and power. Six male taekwondo athletes participated in this study. Measurements of maximal punching with the rear hand (hook and straight punches) and kicking (Apdolio and Dwit Chagi) force were performed on a boxing dynamometer. Also, the following laboratory tests were performed: jump height and power output in counter movement jump (CMJ) and spike jump (SPJ), muscle strength for 10 muscle groups and force-velocity (F-v) relationship. Mean maximal straight and hook punching forces were  $1659.2 \pm 254.2$  N and  $1843.8 \pm 453.3$  N, respectively. Maximal Apdolio rear leg, Apdolio lead leg and Dwit Chagi rear leg kicking forces were  $3541.3 \pm 1130.3$  N,  $3205.3 \pm 965.1$  N and  $3568.0 \pm 1306.0$  N, respectively. The heights of jumps were  $0.501 \pm 0.040$  m (CMJ) and  $0.554 \pm 0.034$  m (SPJ). A strong correlation between the maximal force of a punch and maximal joint torques was observed. The values of kicking forces developed in a simulated fight were lower than the forces developed in the test of individual kicks. Strong relationships were observed between leg power developed in the SPJ and force of individual Apdolio kicks performed with the lead ( $r = 0.87$ ,  $p < 0.05$ ) and rear leg ( $r = 0.74$ ). Based on these findings, it was concluded that maximal joint torques and height of the SPJ could be used as a proxy of kicking force.

**Muhammad Zulhilmi Kaharuddin, Siti Badriah Khairu Razak, et.al (2014)** done Biomechanical Analysis of Combat Sport (Silat) By Using Motion Capture System, 'Silat' is a Malay traditional martial art that is practiced in both amateur and in professional levels. The intensity of the motion spurs the scientific

research in biomechanics. The main purpose of this abstract is to present the biomechanics method used in the study of 'silat'. By using the 3D Depth Camera motion capture system, two subjects are to perform 'Jurus Satu' in three repetitions each. One subject is set as the benchmark for the research. The videos are captured and its data is processed using the 3D Depth Camera server system in the form of 16 3D body joint coordinates which then will be transformed into displacement, velocity and acceleration components by using Microsoft excel for data calculation and Matlab software for simulation of the body. The translated data obtained serves as an input to differentiate both subjects' execution of the 'Jurus Satu'. Nine primary movements with the addition of five secondary movements are observed visually frame by frame from the simulation obtained to get the exact frame that the movement takes place. Further analysis involves the differentiation of both subjects' execution by referring to the average mean and standard deviation of joints for each parameter stated. The findings provide useful data for joints kinematic parameters as well as to improve the execution of 'Jurus Satu' and to exhibit the process of learning a movement that is relatively unknown by the use of a motion capture system.

**Ge Wang, Hui Liu and Peng Liu (2014)** had done biomechanical analysis of hold-throw technique in elite wrestler. This study explores that Kinematic testing can provide the features of wrestling techniques and the strength features can be obtained by using isokinetic dynamometer system. Through above method. With a better understanding of the biomechanical features in wrestling techniques, it is possible to diagnose and evaluate the performance of the wrestler and to provide suggestions for development of skills in training and for competition. Fifteen elite wrestlers were recruited as subjects in this study. Three video recorders operating at 50fps (exposure time 1/1000 s) were set symmetrically to record the wrestler's hold-throw techniques. Aijie Video analyses system was employed to digitize the video records, and to obtain kinematic parameters of subjects' movement. DLT method was used to reconstruct the 3-D space from 2-D image. All digitized coordinates were digitally filtered using a low-pass digital filter with a 10HZ cutoff. Shoulder, elbow, knee and hip joint of subjects were tested for isokinetic torque using MERAC isokinetic testing (Universal Company, USA) and analyses system. Low, 60 degree/ second, and high testing

velocity, 240 degree/second, were employed in this study. When the subject was tested using 60 degree/second, the wrestler was asked to perform flexion and extension of their specific joint 6 times, consecutively. When testing using 240 degree/second, 20 times was required. The distance between the center of gravity of opponent and defender was calculated. From the data it can be shown that the more experienced opponent can keep his CG changing with the defenders at the same time, maintaining the least distance. However, less experienced wrestlers show the contrary. There are two types of movement in knee and hip joint of all wrestlers. The curve of knee and hip joint angle of top level wrestlers is smooth and synchronized. The same curves of less experienced athletes have many fluctuations. Moreover, the range of fluctuation is large. The extension isokinetic peak torque (isokinetic peak torque/weight of wrestler) of shoulder and elbow are larger than flexion. The same result can be found on hip and knee joints. The isokinetic peak torque of high testing speed of both upper limb and lower limb are larger than that of low testing speed. The isokinetic peak torque of subjects is higher than most others reported. The torque ratio of extension and flexion of upper limb is 64% - 92% and lower limb is 49% - 57%. The relationship and change of the center of gravity of two wrestlers provides evaluation of the whole movement. The movements of lower limb can demonstrate the effectiveness of wrestler's techniques. Wrestlers of Beijing team have good strength ability. As far as isokinetic peak torque and torque ratio of extension and flexion concerned, these athletes have good wrestling characteristics.

**Barbas I., Aggeloussis N., Podlivaev B., Shakhmuradov Y. et.al (2014)** had done Biomechanical protocol to assist the training of arm-throw wrestling technique. The purpose of this paper was to present an example of the quantitative contribution of modern sport biomechanics to the training of a competitive wrestling technique, specifically the arm throw in young wrestlers. Two experienced wrestlers who had been training for 10 yrs participated as subjects. The kinematic waveforms were recorded for all body segments using an optoelectronic system with six infrared cameras. The recordings were made in 5 different successful trials. Besides the waveforms, the coefficients of multiple correlations were calculated as measures of each waveform's variability. The results showed that typical repetitive joint angle

waveforms exist in specific joints of the body like the torso, the pelvis and the lower limbs. However, the respective waveforms for the upper limbs showed a very large variability (CMCs<.085). It was concluded, that biomechanical analysis may be a very useful tool for quantifying information on the execution of a complex wrestling technique, such as the arm-throw which can assist the coach in making the adjustments needed to improve the athlete's technique and performance.

### **Studies on Biomechanics in the Field of Sports**

**Liu Lingjun et.al (2022)** study examined the link between kinetic factors and sweeping leg velocity at sweep contact, as well as the kinetics of supporting legs (sweeping and pivot legs) during osoto-gari. In osoto-gari, fifteen black belt judoka competed. A Mac3D motion analysis system was utilised to record motion data at 250 Hz, while four force plates were employed to gather ground reaction force (GRF) data at 1,000 Hz. A significant correlation was observed between the sweeping leg velocity at sweep contact and the peak anterior ( $r = -0.535$ ,  $p = 0.040$ ) and upward ( $r = -0.693$ ,  $p = 0.005$ ) GRFs produced by the sweeping leg, as well as the peak plantar flexion moment ( $r = 0.548$ ,  $p = 0.034$ ) and power ( $r = -0.700$ ,  $p < 0.005$ ) of the sweeping leg ankle joint. The highest clockwise instant ( $r = -0.604$ ,  $p$ ) during the tossing phase connected with the leg velocity peak for sweeping. The sweeping leg velocity at sweep contact was also linked with the pivot leg's peak knee extension moment ( $r = 0.602$ ,  $p = 0.018$ ), hip flexion moment ( $r = -0.589$ ,  $p = 0.021$ ), and knee power ( $r = -0.618$ ,  $p = 0.016$ ). The findings showed that the sweeping velocity was positively correlated with the sweeping leg ankle plantar flexors' exertion. One important biomechanical aspect in speeding the sweeping leg upon sweep contact is contracting the knee extensors of the pivot leg, which increases whole-body rotation.

**Yulong Xiong (2021)** had conducted a Kinematics Analysis and Research on Volleyball Serving Using Computer Technology, As one of the most important competitive sports, volleyball is gradually developed in many countries and regions due to its strong interest and simple operation. Volleyball serve is a basic technique for beginners in volleyball sports. This paper firstly analyzes volleyball serve technology and volleyball serve kinematics. At the same time, it makes use of

computer technology to analyze volleyball serve kinematics for readers' reference. Three-dimensional camera is one of the commonly used methods in sports technology research in recent years. Three-dimensional kinematics analysis originated in the mid-1980s and was first applied to track and field technology by foreign scholars. In the 1990s, some domestic scholars gradually began to analyze various movements from the three-dimensional perspective, and some effective results have been achieved. Japan started earlier in this aspect, from the early 1990s began to be used in volleyball technology research. With the advent of high-definition digital camera and the further development of 3D video analysis software, the 3D camera method becomes more and more accurate and its practical scope becomes wider and wider. Compared with 3D high-speed photography, 3D photography uses video tape instead of film, which can save a lot of money. Therefore, a lot of technical actions, even the whole game, can be shot according to the needs during the competition. It enables researchers to have a greater choice, with large sample content, strong representativeness and high credibility. In the process of action analysis, the technical action can be repeated and observed carefully, which brings convenience for researchers. Sports is a complex three-dimensional human activity. To sum up, in the course of volleyball service training, we should pay attention to the training of throwing, running, taking off and hitting in the air to improve the effect of volleyball service. At the same time using the computer technology to study volleyball serve, volleyball serve the process of one step to explore, promote the development of volleyball serve.

**Thorben Menrad, Jürgen Edelmann et.al (2021)** had done a research on Validation of Velocity Measuring Devices in Velocity Based Strength Training to control and monitor strength training with a barbell various systems are on the consumer market. They provide the user with information regarding velocity, acceleration and trajectory of the barbell. Some systems additionally calculate the 1-repetition-maximum (1RM) of exercises and use it to suggest individual intensities for future training. Three systems were tested: GymAware, PUSH Band 2.0 and Vmaxpro. The GymAware system bases on linear position transducers, PUSH Band 2.0 and Vmaxpro base on inertial measurement units. The aim of this paper was to determine the accuracy of the three systems with regard to the determination of the

average velocity of each repetition of three barbell strength exercises (squat, barbell rowing, deadlift). The velocity data of the three systems were compared to a Vicon system using linear regression analyses and Bland-Altman-diagrams. In the linear regression analyses the smallest coefficient of determination ( $R^2$ ) in each exercise can be observed for PUSH Band 2.0. In the Bland-Altman diagrams the mean value of the differences in the average velocities is near zero for all systems and all exercises. PUSH Band 2.0 has the largest differences between the Limits of Agreement. For GymAware and Vmaxpro these differences are comparable.

**May, Bradley & May, Dior. (2021)** had conducted a Biomechanical analysis of the knee during long jump. A series of horizontal jumps made by the experienced male athlete was recorded with a piezoelectric force plate (PFP) and velocity using a high-speed video camera. The velocity range of the athlete was obtained by using both electromyography (EMG) and direct intervention by setting the length of run-up. During this jumping phase, the horizontal velocity was considerably decreased at the point of take-off. The braking impulse of the athlete was found to be increasing with an increase in velocity. However, the take-off technique was varied between the desires of generating vertical impulse and reducing the horizontal braking impulse. The main objective study was, therefore, to correlate the effect of knee joint with take-off force. A male athlete aged twenty-two, height 1.7 m, weights 58 kg, and personal best long jump of 5.81 m conducted a series of long jumps. The run-up lengths varied, both horizontal and vertical reactions components of forces were obtained using a piezoelectric force plate (PFP) set at a frequency of 1000 Hz (Table 1). The video images of the athlete were captured using the JCV GR9800 camera, operating at a rate of 100 Hz. The motion of the athlete was obtained by using a digitized video image. However, the vertical and horizontal velocities during take-off were obtained by calculating the data formed on the piezoelectric force plate. The information from the video analysis was also used to obtain variables such as the COM, the horizontal position and the knee angle of the athlete. In conclusion, there is a clear analysis of the knee joint in relation to the take-off force. The results showed that the efficiency of long jump is defined mostly by the following take-off parameters: horizontal velocity, vertical velocity, speed, and angle of projection. The final vertical velocity

in a long jump is achieved by maximum knee flexion, which indicates that the pivot mechanism is the single most important mechanism acting to create vertical velocity during the take-off. Furthermore, the ability of the individual to have a low take-off angle to allow for braking impulse reduction will enhance the landing for optimal distance. However, it is essential to note that as the braking impulse increases, the landing distance decreases.

**Daniel Brandao Kashiwagura et.al (2021)** had conducted a study on Judo technical-tactical dynamics: analysis of attack system effectiveness in high-level athletes. The purpose of this study was to identify the assault strategies that produced the best results in judo matches. We looked at 5847 attacks from 152 male international medallists at the highest level. Six factors were examined in detail for each attack, including the attacker/defender's approach, grip, stance, final displacement, and attack direction. Both successful (scoring) and unsuccessful (no-score) attacks were examined. The odds ratio (OR), logistic regression, and decision tree analysis were used to compute the likelihood of success for each attack scheme. The findings showed that: i) a successful attack required gripping the dorsal region; ii) the most effective grip configuration was Right-Dorsal & Left-Dorsal ( $P < 0.01$ ,  $OR = 3.08$ ), followed by Right-Dorsal & Left-Sleeve ( $P < 0.01$ ,  $OR = 1.79$ ) and Right-Sleeve & Left-Dorsal ( $P < 0.01$ ,  $OR = 1.72$ ); iii) a hierarchical technical-tactical analysis revealed that the direction of attack and stance had a significant impact on the scoring rates for individual grips. This is the largest study on attack efficacy in judo to date, therefore the information provided here may be useful to coaches in organizing battle dynamics in a new and useful way and in helping to develop offensive and defensive strategies that will enhance judo performance.

**Adam Barzil, Laurie Needham, Jac L. Palmer, et.al (2021)** done a comprehensive biomechanical analysis of the barbell hip thrust. Barbell hip thrust exercises have risen in popularity within the biomechanics and strength and conditioning literature over recent years, as a method of developing the hip extensor musculature. Biomechanical analysis of the hip thrust beyond electromyography is yet to be conducted. The aim of this study was therefore to perform the first

comprehensive biomechanical analysis the barbell hip thrust. Nineteen resistance trained males performed three repetitions of the barbell hip thrust at 70% one-repetition maximum. Kinematic (250 Hz) and kinetic (1000 Hz) data were used to calculate angle, angular velocity, and moment and power data at the ankle, knee, hip and pelvic-trunk joint during the lifting phase. Results highlighted that the hip thrust elicits significantly ( $p < 0.05$ ) greater bilateral extensor demand at the hip joint in comparison with the knee and pelvic-trunk joints, whilst ankle joint kinetics were found to be negligible. Against contemporary belief, hip extensor moments were not found to be consistent throughout the repetition and instead diminished throughout the lifting phase. The current study provides unique insight to joint kinematics and kinetics of the barbell hip thrust, based on a novel approach that offers a robust evidence base for practitioners to guide exercise selection.

**J. Rossi, S. Vitulli, D. Poncet, P. Edouard, H. Largeron & S. Sangnier (2020)** Biomechanical analysis of different knee angle starting positions in nordic hamstring exercise. The aim of the present study was to analyse the effect of knee angle starting position on the kinetic and kinematic adaptations during the NHE. More precisely, we studied the spontaneous motricity used in order to lowering their upper body towards a prone position, as slowly as possible until participant can no longer control the lowering. Nine healthy male with previous experience with NHE ( $24 \pm 7$  years,  $180 \pm 7$  cm,  $79.4 \pm 8.2$  kg) participated in the study. All participants were free of lower limb injury in the twelve months prior to data collection. Informed written consent was obtained from all participants prior to data collection. After a 10 min warm-up consisting of light cycling aerobic activity, each participant performed two series of 10 repetitions of manual resistance eccentric contractions of the hamstrings. After the warm-up, on both leg, two EMG surface electrodes (TrignoWireless EMG Systems; Delsys, Boston, MA, USA) were placed on semitendinosus and biceps femoris and kinematic markers and clusters were attached on the different segments. Two force sensors were fixed on both ankles to measure contact forces normal to the lower leg at 200 Hz and synchronized with 12 cameras of an optoelectronic motion capture system (Motion analysis corporation, Raptor 4, Santa Rosa, USA) in order to track 32 reflective markers at 200 Hz to record

kinematics of every trial. Surface EMG signals were sampled at 2000 Hz. The NHE were tested in randomized order for three conditions of different knee angle starting position (0° (i.e. leg support align with the floor), 20° and 30° relative to the ground respectively). For each slope condition, participants were asked to perform three repetitions of the NHE. Each participant performed a familiarization session before the study. The rest between each trials of the same knee angle starting position was 2 min and 5 min between each slope. Knee angles (defined as rotation between the distal and proximal segment using Euler angles with a rotation sequence Z (F-E), Y (A-A), X (P-S), negative values correspond to knee flexion), knee angular velocity and maximal forces for both legs were computed with Visual3D software (C-Motion, Germantown, USA). Standard statistical methods were used to compute means and standard deviation of the parameters studied for each participant and each condition. The peak EMG activity for all muscles, which was determined as highest mean value on 250 ms window length during the movement, was computed. Three repeated measures ANOVA were used to identify the effect of slope condition. Newman Keuls post-hoc test was used when significant level ( $p < 0.05$ ) was reached. The results of the present study suggest that using different start positions when performing NHE might be of interest to adapt the difficulty and thus obtain a better control of the movement and work on a greater range of motion without the help of external equipment.

**Sivana Nagi et.al (2019)** done a study on Successful transition to groundwork combat during Junior and Senior Judo World Championships. The primary goal of this study was to describe the successful transition phases from standing combat to groundwork combat in a high-level judo competition (the 2017 World Championship) in order to determine the type of transition (turtle, supine, prone, half-guard, besides, guard, standing, and seated) and rhythms (i.e. time spent by the scoring athletes) that these athletes primarily employed. Our sample was drawn from the 2017 Judo World Championships for juniors and seniors, men and women. The transition phases ( $n = 373$ ) that resulted in a score during the junior ( $n = 179$ ) and senior ( $n = 194$ ) periods were examined. The major outcomes of this study revealed an instantaneous correlation between standing and groundwork movements in over half of the cases.

The majority of scoring actions (~75%) were obtained by osae-komi-waza (immobilization strategies), which were primarily performed while the match was deadlocked (~71%). There were no significant differences ( $p > 0.05$ ) between sex and age groups in terms of technique and body posture. The various forms of transitions were used in comparable ways throughout the competition stages, demonstrating that athletes must be able to deal with a variety of scenarios in the transition phase in order to be successful.

**Benjamin R. Hindle, Paul Winwood et.al (2019)** gone through the Biomechanics and Applications of Strongman Exercises: a Systematic Review. The sport of strongman is becoming increasingly popular, catering for females, lightweight, and Masters Competitors, with strongman exercises also being used by strength and conditioning coaches for a range of athletic groups. Thus, a systematic review was conducted to examine researchers' current understanding of the biomechanics of strongman exercises, with a view to improve strongman athlete performance, provide biomechanical evidence supporting the transferability of strongman exercises to strength and conditioning/rehabilitation programs, and identify gaps in the current knowledge of the biomechanics of strongman exercises. A two-level search term strategy was used to search five databases for studies relevant to strongman exercises and biomechanics. Eleven articles adherent to the inclusion criteria were returned from the search. The studies provided preliminary biomechanical analysis of various strongman exercises including the key biomechanical performance determinants of the farmer's walk, heavy sled pull, and tire flip. Higher performing athletes in the farmer's walk and heavy sled pull were characterized by a greater stride length and stride rate and reduced ground contact time, while higher performing athletes in the tire flip were characterized by a reduced second pull phase time when compared with lower performing athletes. Qualitative comparison of carrying/walking, pulling and static lifting strongman, traditional weight training exercises (TWTE), and common everyday activities (CEA), like loaded carriage and resisted sprinting, were discussed to further researchers' understanding of the determinants of various strongman exercises and their applications to strength and conditioning practice. A lack of basic quantitative

biomechanical data of the yoke walk, unilateral load carriage, vehicle pull, atlas stone lift and tire flip, and biomechanical performance determinants of the log lift were identified. Previous studies have benefited from the use of video and manipulated footage to provide kinematic data (Bezodis *et al.*, 2008, Hunter *et al.*, 2004; Bushell & Hunter, 2007) whilst some have used motion analysis systems (Gittoes & Wilson, 2010) that identify joint centres on the physical body by using markers and scanners that input the data from the markers that move with the participant straight into a computer. Video analysis takes longer to process, individually digitising and estimating joint centres from a two dimensional projection on screen, motion analysis system can take the information from the scanners and markers on participants straight into computer software to be analysed. Video analysis, however has the benefit of being non-invasive providing maximum ecological validity allowing the athlete to run in their normal running patterns, but limits the accuracy and precision of the procedure. The motion analysis system is much more accurate and a more modern approach to investigating kinematics, however the markers are attached to the body and may cause discomfort for the athlete that may alter their technique.

**Francesca E. Wade, Kam-Ming Mok .et.al (2018)** had done a study on Kinematic analysis of a televised medial ankle sprain. Ankle sprains are one of the most prevalent athletic injuries. Prior work has investigated lateral ankle sprains, but research on generally more severe medial sprains is lacking. This case report performs a kinematic analysis using novel motion analysis methods on a non-contact medial ankle sprain. Peak eversion ( $50^\circ$ ) occurred 0.2 seconds following ground contact, maximum velocity of  $426^\circ/\text{s}$ , while peak dorsiflexion ( $64^\circ$ ) occurred with a greater maximum velocity ( $573^\circ/\text{s}$ ). The combination of dorsiflexion at ground contact and rapid eversion is associated with a non-contact eversion sprain. This study provides a quantitative analysis of the eversion ankle sprain injury mechanism. A virtual environment of the American Football field was reconstructed using the dimensions outlined in the NFL rule book, with one meter equal to 0.41 Poser units, or a 41% scale. For each injury view, the reconstructed field was manually aligned with the recorded field by adjusting the camera orientation, position and focal length. Once focal length was identified in the first frame, it remained constant throughout

matching. The overall motion of the skeletal model was assessed and adjusted by two additional researchers to ensure a smooth motion. Individual segment parameters, such as foot segment bend, twist and turn, were evaluated by the same researcher who conducted the initial matching to manually smooth each parameter's angle curve, minimizing the noise in the computed velocities. At the point of initial ground contact, time zero, the ankle joint was 11° plantar flexed, 32° externally rotated and 12° everted. At the moment of peak eversion, occurring 0.2 seconds after initial contact, the ankle joint was 39° dorsiflexed, 30° externally rotated and 50° everted. At this time, there was minimal eversion velocity (78°/s) and high dorsiflexion velocity (569°/s), while internal rotation did not change. The maximum eversion velocity (426°/s) occurred immediately following ground contact. Peak dorsiflexion occurred at 0.27 seconds following ground contact later than that of peak eversion, although peak dorsiflexion velocity is observed with peak eversion. Internal rotation remains constant throughout the contact phase. The present study used quantitative analysis to analyze ankle joint kinematics in an ankle eversion sprain case that occurred in an American Football quarterback. The results suggest a case-specific injury mechanism comprising of sudden eversion and dorsiflexion, with constant internal rotation, agreeing with the clinical qualitative pathology. It is hoped this MBIM analysis starts the discussion for further research into the injury mechanism of medial ankle sprain injuries.

**Athanasios Psarras, Dimitra Mertyri, and Panagiotis Tsaklis (2016)** had done Biomechanical analysis of ankle during the stance phase of gait on various surfaces, The purpose of this article is to review the literature that deals with the biomechanical analysis of the ankle during gait stance phase on slopes, on uneven and rock surfaces, on sand, and on grass surfaces, as well as to present the observed differences. The literature was searched in the databases of PubMed and Google Scholar, for the years of 2005–2015. The keywords were: biomechanics, gait analysis, ankle joint, stance phase, uphill walking, downhill walking, sand surface, uneven surface, grass surface, and ballast. The kinetic and kinematic gait behaviour is directly influenced by the surface on which it is being performed. The uphill or downhill surfaces, the surfaces of stone, sand, grass, and uneven surfaces have a direct impact

on the biomechanics on joints of the lower limb, changing the energy cost, muscle activation, the resulting mechanical work, ground reaction forces and balance, and the parameters of the gait cycle. All these changes are raising many questions about the safety and comfort of these surfaces. In the structures of the foot, ankle and lower leg high compressive and rotational forces are transmitted resulting in injuries in these regions. Each surface has its own advantages and disadvantages, changing the biomechanics of the lower extremity and particularly the ankle. According to the purpose that one wants to achieve they can choose a suitable surface. To prevent injuries and falls, we must choose shoes that fit well, are comfortable with cushioning, and have a feeling neither too hard nor too soft, with laces and low collar.

**Ewa polak, Jerzy kulasa, António vencesbrito et.al (2015)** had explored Motion analysis systems as optimization training tools in combat sports and martial arts. Over the past years, a few review papers about possibilities of using motion analysis systems in sport were published, but there are no articles that discuss this problem in the field of combat sports and martial arts. This study presents the diversity of contemporary motion analysis systems both, those that are used in scientific research, as well as those that can be applied in daily work of coaches and athletes in combat sports and martial arts. An additional aim is the indication of example applications in scientific research and range of applications in optimizing the training process. It presents a brief description of each type of systems that are currently used in sport, specific examples of systems and the main advantages and disadvantages of using them. The presentation and discussion takes place in the following sections: motion analysis utility for combat sports and martial arts, systems using digital video and systems using markers, sensors or transmitters. Not all types of motion analysis systems used in sport are suitable for combat sports and martial arts. Scientific studies conducted so far showed the usefulness of video-based, optical and electromechanical systems. The use of research results made with complex motion analysis systems, or made with simple systems, local application and immediate visualization is important for the preparation of training and its optimization. It may lead to technical and tactical improvement in athletes as well as the prevention of injuries in combat sports and martial arts.

**Almansba, E. Franchini and S. Sterkowicz (2007)** conducted a study on Uchi-komi avec charge, une approche physiologique d'un nouveau test spécifique au judo. The aim of this study was to elaborate and validate a specific test to evaluate the physical condition of judo players. **Subjects and methods.** – Twenty-three volunteers, males, aged  $22 \pm 3.62$  years old took part in our experiment. They did the progressive test of Leger et al. (1984), vertical Jump test (Sargent test), Australian shuttle run test and a specific judo test. **Results.** – The observed results showed significant correlations between muscular power and the number of Uchi-komi on the judo test reference scale ( $R = 0.52, P < 0.01$ ). Furthermore, there were other correlations between the number of Uchi-komi at the two first sets of specific judo test and the anaerobic power represented by the distance covered in 30s at the Australian shuttle test ( $R = 0.86, P < 0.01$ ), also between the anaerobic capacity represented by the whole distance covered and the total number of Uchi-komi achieved at the judo test ( $R = 0.88, P < 0.01$ ). **Conclusion.** – The test reproduces the physiological characteristics of judo fight. It is a good indicator of the judoka's physical fitness and their cardiovascular adaptation in a physical effort.

**Jackie L. Hudson (1983)** had done a biomechanical analysis by skill level of free throw shooting in basketball. Free throw shooting in basketball is a task which falls into two broad categories of sports skills. First, it is a task of accuracy. Second, it requires submaximal velocity for most populations of players. Because of the submaximal velocity demands, there are endless combinations of segmental contributions in conjunction with numerous projection angles and velocities which can result in shots which directly or indirectly fall through the basket. In addition to the segmental actions which contribute to shooting performance, there may be other actions which are extraneous to performance. These non-related characteristics can be termed style. Since the identification of characteristics which are consistently employed by skilled performers and conspicuously absent in poor performers may lead to improved teaching and coaching, this study was conducted to analyze selected biomechanical parameters of free throw shooting by players of varying skill. Three mutually exclusive groups of college women served as subjects for this study. The nine members of the high skill group were competitors on the United States team in

the World University Games. Seven non-scholarship players on a varsity team comprised the moderate skill group. The low skill group consisted of nine members of an instructional class. The testing protocol for each subject involved: 1) a subject-controlled warm-up period. 2) an accuracy test of 20 free throw trials. 3) marking of bony landmarks with colored. Cloth tape. 4) additional warm-up time to adjust to the tape. and 5) three free throw trials which were recorded for analysis. Film records were taken by a 16 mm Cine-Kodak Special camera which was located 23 m from the right side of the subject on an extension of the free throw line. Camera speed was 64 frames per second with an exposure time of 4 ms. Points on the periphery of the basketball and the end of segments were digitized with a Vanguard Motion Analyzer. These data and segmental data from Dempster (1955) were supplied to a FORTRAN program to obtain the appropriate mathematical results. To analyze the projection characteristics of the basketball it was necessary to know the location of the ball center. A method of triangulation, using coordinate data from three points on the periphery of the ball, was employed to locate the center of the ball. The horizontal and vertical components of ball velocity were found by using the displacement of the ball center, the elapsed time between frames, and the equations of motion. The resultant velocity of the ball was calculated from the component velocities. The angle of projection was the angle formed by the resultant velocity and the horizontal. Trunk inclination was measured in degrees with vertical being 00 and a forward inclination being positive. The base of support was defined as the horizontal distance from the rear ankle to the leading toe. The distance the frontal aspect of the center of gravity was in advance of the trailing ankle was divided by the length of the base of support to yield the center of gravity ratio. The height of release ratio was computed by dividing the height of the ball center at release by the height of the shooter. Analysis of variance techniques and the 0.05 level of significance were used to determine if the groups were similar in the parameters of execution. Greater stability (i.e. balanced center of gravity and vertical trunk inclination) is related to higher skill. A greater ratio of height of release to standing height is related to higher skill. Angle and velocity of projection taken independently. Are not related to skill level.

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## Chapter III

# METHODS AND PROCEDURE

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Selection of Participants .....	81
Selection of Variables.....	82
Conceptual clarification in the throwing dynamics and static actions of selected judo techniques .....	87
Selection of Equipment .....	100
Reliability of Data .....	102
Motion Capture Protocol .....	102
Collection of Data.....	104
Statistics.....	105
Level of Significance .....	105
Research Design.....	106

To carry out a comprehensive biomechanical analysis of judo techniques, it is essential to establish a rigorous methodology that ensures accurate measurement and interpretation of kinematic variables involved in the execution of these techniques. The methodology involves the selection of specific judo techniques for analysis, the use of motion capture technology to record and analyze the movements, and the application of biomechanical principles to interpret the data collected. This chapter contains an elaborated description of the procedure adopted for the selection of participants, selection of variables, selection of techniques, selection of Equipment, reliability of data, collection of data and statistical techniques for the analysis of data.

### **Selection of Participants**

The technical performance of Judokas who were participated in all India interuniversity judo championships held from 2017 to 2022 consecutive years the scholar collected primary as well as secondary video data which were relevant to the study. The technical performance of the participants of All India Interuniversity Judo Championships (2019-20 and 2021-22) were subjects to the practical application of the selected Tachi Waza techniques for scoring an Ippon or Waza-ari from each of the weight categories specified by the International Judo Federation. The age of the participants ranged from 18 to 25.

### **Selection of Variables**

In view to the purpose of this study, kinematical variables as dependent variables, judo techniques and competition weight categories as independent variables were chosen, taking into account the available information and literature reviews as well as the availability of equipment, especially with expert guidance based on the

researcher's evidence. Detailing of the selected dependent and independent variables are follows.

### **Selection of Dependent Variables**

Six kinematic variables namely Angular velocity, Angular displacement, Movement time, Height of center of gravity, Angle of hip flexion, and Angle of knee flexion are chosen. Detailing of selected dependent variables are as follows:

**Table 1**

*Selected Dependent Variables*

<b>Sl. No.</b>	<b>Variables</b>	<b>Criterion</b>
1.	Angular Velocity	Degree/sec
2.	Angular Displacement	Degree
3.	Movement Time	Sec
4.	Height of CoG	Cm
5.	Angle of Hip Flexion	Degree
6.	Angle of Knee Flexion	Degree

#### **1. Angular Velocity**

The angular displacement traversed per unit time was used to determine angular velocity.

$$\omega = \frac{\theta}{t}$$

Where,  $\omega \Rightarrow$  average Angular Velocity and  $\theta \Rightarrow$  Angular Displacement (Deg),  $t \Rightarrow$  Time in sec

Its unit measures

$$\frac{\text{Degree}}{\text{Sec}} \text{ or } \frac{\text{Radian}}{\text{Sec}}$$

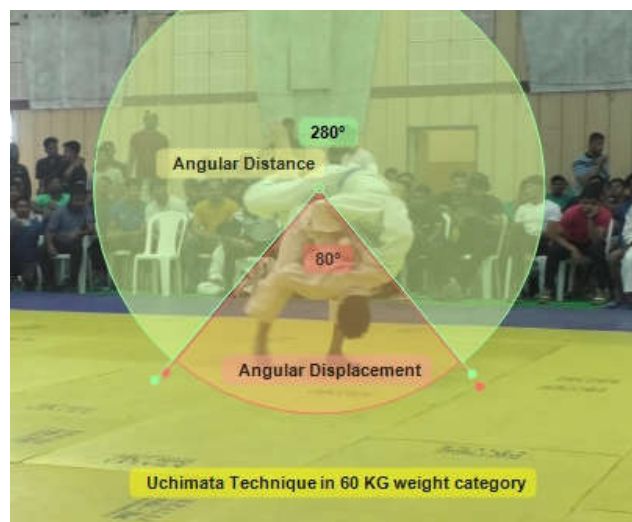
Conversion formula for degree to radian – Radian =  $\left( \text{Degree} \times \frac{\pi}{180} \right)$

## 2. Angular Displacement

A change in the angular location or orientation of a line segment is referred to as angular displacement. It is assessed as the difference in the initial and final positions of the moving body (Susan J., 1953). The lesser of the two angles between the rotating body of Uke beginning and final positions was used to determine the angular displacement. Its Unit measures were Degree (deg°) were converted in to Radian.

**Figure 11**

*Determination of Angular Displacement*



## 3. Movement Time

The time it took to complete a movement or technique by the Tori, was used to calculate Movement Time.

Its unit measure were in seconds (Sec)

## 4. Height of Center of gravity (CoG.)

During the Tsukuri phase of technique, the distance from the floor to the point where the body's weight and mass of Tori were equally balanced. The xcg and ycg coordinates of the CoG of the body position were calculated using the formula of xcg and ycg coordinates of the body position were found using the joint point method.

$$x_{cg} = EGT_i \times \frac{x_i}{100}$$

$$y_{cg} = EGT_i \times \frac{y_i}{100}$$

Where,  $GT_i \Rightarrow$  Relative Weight,  $x_i \Rightarrow$  x coordinate of the frame,  $y_i =$  y coordinate of the frame, 100  $\Rightarrow$  constant

**Figure 12**

*Determination of Height of CoG*



## 5. Angle of Hip Flexion (Hip Angle)

In the Tsukuri phase of technique, the angle of the hip flexion of Tori was measured at the angle of hip. The hip angle was defined as the angle between the left acromion process to the great trochanter and the left great trochanter to the knee (Glassbrook et al., 2017).

Its Unit measures were Degree (deg<sup>0</sup>)

**Figure 13**

*Determination of Angle of Hip Flexion*



#### 6. Angle of Knee Flexion (Knee Angle)

During the Tsukuri phase of technique, the angle of the supporting Knee joint flexion of Tori was measured at the angle of Knee flexion.

Its Unit measures were Degree (deg<sup>0</sup>)

**Figure 14**

*Determination of Angle of knee flexion*



The angles were estimates of the anatomical angles calculated from lines formed between the center of reflective markers (Tillaar, Roland & Knutli, Tom & Larsen, Stian. 2020).

### **Selection of Independent Variables**

Illustration and detailing of selected independent variables, judo techniques and competition weight categories were shown below.

#### *Selection of Judo Techniques*

The researcher reviewed available videos of International Judo Championships and directly observed various National Judo Championships, and All India Inter university judo championships, based on various articles and observations, noticed that the following judo techniques and variations are most commonly used by competitors to win Judo Championships. As a logical result, the researcher selected the following judo techniques as independent variables for analysis, to satisfy the objectives of this research.

**Table 2**

#### *Selected Judo Techniques*

<b>SI No.</b>	<b>Techniques</b>	<b>Tachi Waza Classification*</b>
1.	Ippon-Seoi-Nage	
2.	Seoi – Otoshi	Te Waza (Hand Techniques)
3.	Tai – Otoshi	
4.	O- Ghoshi	
5.	Harai Goshi	Koshi Waza (Hip Techniques)
6.	Koshi Guruma	
7.	Osoto Gari	
8.	Uchimata	Ashi Waza (Leg Techniques)
9.	Ouchi Gari	

Source: [kodokanjudo.institute.org/en/wasa/list/](http://kodokanjudo.institute.org/en/wasa/list/)

\* Kodokan (1985)

## Conceptual clarification in the throwing dynamics and static actions of selected Judo Techniques

### Phases of Judo Technique

#### Phase I:- Kumikate (Basic Gripping)

In judo, the basic grips (Kumi kate) are performed by gripping the opponent's lapel with one hand and the sleeve with the other in shizentai (natural posture) and jigotai (defence posture). During attack and defence, a judoka could employ kumikata to gain control of the opponent and make good use of techniques. There are two types of variations allowed in judo, according to the international judo monitoring body: conventional and unconventional. Conventional gripping is the basic gripping used to begin a match by both judokas clutching each other's sleeve and lapel. Except for the other grasping, which is regarded unusual and must not last longer than fifteen seconds.



Scan QR Code for virtual demonstration

#### Figure 15

*Kumikata variations in Sizentai (Normal Posture) and Jigo tai (Defensive posture)*





**Phase II:- Kuzushi (Off balancing)**

Shihan Jigoro Kano developed Kusushi, the soul of Judo techniques, from his observations and investigations of mechanics and human anatomy. Kusushi used to unbalance the opponent, destroying his ability to attack and defend so that he can throw the opponent with least effort and maximum effectiveness. The 'hikite' arm pulling and the 'surite' body lifting are the two aspects of the kusushi technique. Hikite dictates the direction of highkite throw, whereas surite is utilised to unbalance the uke by raising its center of gravity.

**Figure 16**

*Kuzushi Offbalancing*

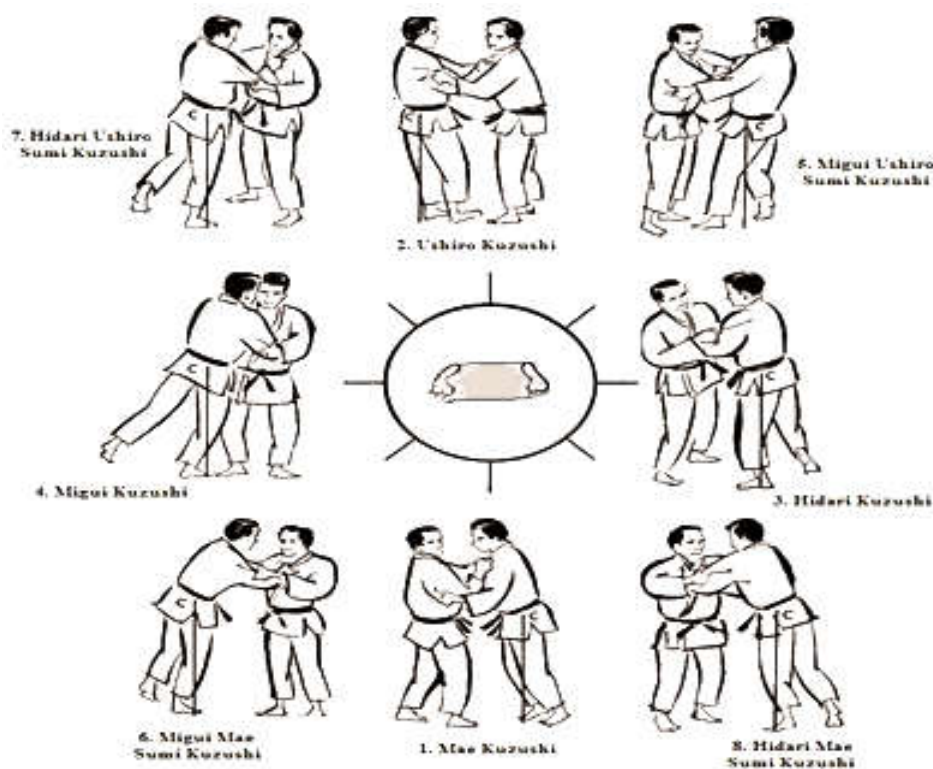


**The kuzushi directions are as follows:**

1. Mae-kuzushi – Forward Off Balancing.
2. Ushiro-kuzushi - Backward Off Balancing.
3. Hidari-kuzushi - Left Side Off Balancing
4. Migi-kuzushi - Right Side Off Balancing
5. Migi-ushiro-sumi-kuzushi - Backward Off Balancing to the Right side Corner.
6. Migi-mae-sumi-kuzushi - Forward Off Balancing to the Right side Corner
7. Hidari-ushiro-sumi-kuzushi – Backwards Off Balancing to the Left side Corner
8. Hidari-mae-sumi-kuzushi – Forward Off Balancing to the Left side Corner.

**Figure 17**

*Kuzhushi (Method of off balancing)*



### **Phase III:- Tsukuri (Body fitting)**

Tsukuri is the entry and proper fitting of your body into the position required for the completion of the throwing method just before the required instant. Tori must bring his own body into a throwing position in order to make a perfect throw. The criterion is that Tori has already damaged the Uke's balance (Kuzushi) and can take advantage of this instability. Uke will strive to avoid falling by compensatory movements or blocking. Tori must move quickly and precisely throughout his attack. There are several ways to turn into a throw in the Judo sport (Tai sabaki).

### **Figure 18**

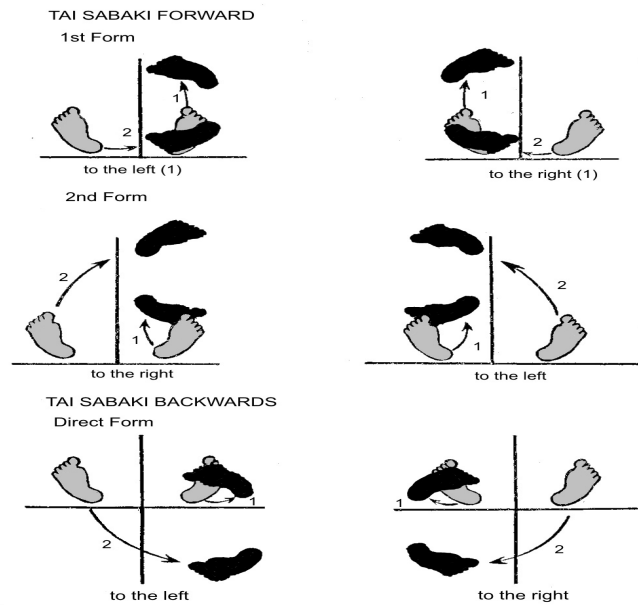
*Tsukuri (Body fitting/Positioning)*



**Tai Sabaki** ('body-management') is a collection of corporal movement practices in judo, the idea is to step to the attack line and allow the body to take up position so that a technique may be applied. Tai Sabaki is an important component of successful technique execution.

**Figure 19**

*Tai Sabaki (foot movements while positioning of Body)*



#### **Phase IV:- Kake (Execution of Technique)**

It's the throw's final, most forceful execution. Tsukuri and Kuzushi are two sides of the same movement. The main activity of the kake is the coupling of forces from various body parts and the physical application of a lever.

**Figure 20**

*Kake (Execution of Technique)*



### **Ippon-Seoi-Nage (SON) – One Arm Shoulder Throw**

With a right-foot front turning movement, drop the body while maintaining close back contact with the ukes' chest, bend the right arm and push the elbow under the ukes' armpit, and throw over the shoulder.

Phase I : Force the uke off balance with a right foot front turning action.

Phase II : Place Toris' torso in front of the uke, pressing the right elbow into the uke's right armpit while maintaining close back contact with the uke's chest.

Phase III : With the left arm, pull toward the front, while the right arm pushes up and over.

Phase IV : Straighten your legs and toss to the front over your shoulder.

#### **Figure 21**

*Execution of Ippon-Seoi-Nage (One Arm Shoulder Throw)*



## Seoi – Otoshi (SOO)- Kneeling Shoulder Drop

Seoi-otoshi is accomplished by pulling in a straight forward or right forward motion, which throws your opponent off balance. Then, when tori drops one or both knees on the mat, bring up Uke's body on tori's back and continue pulling to throw over the shoulder.

- Phase 1 : Tori pushes Uke straight forward to throw him off balance, then takes a step back with her right foot and places it in front of Uke's right foot.
- Phase 2 : Tori bends both knees and spins left with the point of his right foot, while his right arm is placed under the Uke's right arm pit. He then grabs Uke's right arm and pulls it up against his chest.
- Phase 3 : In the Ippon-seoi-nage position, Uke is hoisted up.
- Phase 4 : Tori stretches his right leg to the inside of Uke's right foot, then lowers his torso to the mat and inserts his right knee.

### Figure 22

*Execution of Seoi-Otoshi (Kneeling Shoulder Drop)*



### **Tai – Otoshi (TOS) – Body Drop**

Tori moves his left foot back, widens the gap between him and Uke, unbalances Uke to his right front, and throws with his right foot in front of Uke's right ankle.

Phase I : Tori transfers Ukes weight onto his toes by drawing his left foot to his right rear, unbalancing him to his right front corner.

Phase II : Using the right foot to enter.

Phase III : Make use of your ankle as a fulcrum.

Phase IV : Throw while pulling with the left hand and pushing with the right.

### **Figure 23**

*Execution of Tai-Otoshi (Body Drop)*



## O- Ghoshi (OGO)- Major Hip Throw

To perform o-goshi, tori shifts ukes weight to his front and turns his back on him. The right hand is placed over the belt and reaches behind the left arm of the player. Lower the hips and toss to the front, pushing the uke tightly with both hands. Lower the hips and toss to the front, pushing the uke tightly with both hands.

Phase I : From a defensive stance, pull uke toward you with tori's right hand, causing him to step forward with his left foot.

Phase II : Quickly wrap tori's right arm around uke's waist and pull him toward tori's right hip, causing uke to lose his balance and fall to the front.

Phase III : Pivot around, your right foot parallel to uke's foot and tori's left foot slightly in front of uke's left foot.

Phase IV : Bend tori's knees and pull the uke up against her right hip. Lift him up by straightening tori's knees while pulling with her left arm, twisting to the left and throwing.

### Figure 24

*Execution of O-Goshi (Major Hip Throw)*



### **Harai-Goshi (HRG) –Sweeping Hip Throw**

Tori shifts uke's weight to his right front corner, pivots and pulls him to him, then sweeps uke's right thigh with tori's right thigh.

Phase I : Start in a comfortable, natural position. Break ukes equilibrium by pulling and raising with both hands as tori steps back with his left foot. Swing your left foot in front of his and place it in front of him.

Phase II : Pull with both hands at the same time until uke's chest and abdomen touch tori's torso.

Phase III : Sweep up and outward against uke's thigh with the back of tori's thigh, sticking his right leg past his right leg.

Phase IV : With both hands, twist to the left and pull hard forward and downward. In front of tori, uke will land on his back.

### **Figure 25**

*Execution of Harai-Goshi (Sweeping Hip Throw)*



## Koshi-Guruma (KOG) – Hip Wheel

Tori positioned his right front corner and right hip solidly on uke and threw him over it while shattering uke's balance to his right front corner.

Phase I : Step back with tori's right foot from the right natural posture, causing uke to step forward with his left foot.

Phase II : Gently pull with both hands until uke's toes are supported. Place tori's right foot near uke's right foot and uke's right arm around tori's neck or shoulder.

Phase III : Continue pivoting, pushing tori's left foot back until his right hip is on uke's abdomen to the left. Tori's right hip was slammed down hard.

Phase IV : Twist toward tori's left front while elevating her hips and pulling to the front with both hands. Uke will land in front of tori after falling over his hip.

### Figure 26

*Execution of Koshi-Guruma (Hip Wheel)*



### **O-Soto-Gari (OSG)- Major Outer Reap**

Tori shifts uke's balance to his right rear corner, causing him to shift all of his weight to his right heel and reap his right leg.

Phase I : Starting in the proper natural stance, gently bring uke to his right front corner and have him take a step forward with his right foot. To break his balance, place your left foot outside his right foot and draw him toward you with your left hand while pushing him backward with Tori's right.

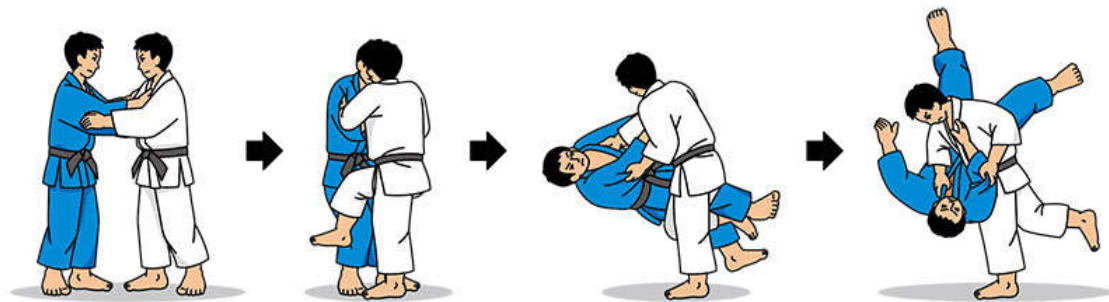
Phase II : Raise and swing tori's right leg past uke's right leg. With tori's thigh, clip his thigh hard from behind.

Phase III : With tori's left hand, pull down firmly and with his right hand, push toward uke's right rear corner.

Phase IV : Uke's legs will fly up and he will fall backwards in a straight line.

#### **Figure 27**

*Execution of O-Soto-Gari (Major Outer Reap)*



### **Uchimata (UMA) – Inner Thigh Throw**

In the Uchi Mata technique, Tori throws uke over tori's thigh in a turn throw.

Phase I : Tori wants a firm grip on Uke. This is a collar and sleeve grip, which puts tori in command. Uke's stance and arm are under Tori's control.

Phase II : It's usually done while the uke is in a defensive stance with his legs extended and his arms pushed out in front of him while his upper body is bent forward.

Phase III : Tori pivots or hops into position between Uke's feet, facing the same direction as Uke. To complete the toss, pick up the uke and continue to turn and roll forward.

Phase IV : Slide the second leg between the legs of the uke. As tori leans forward and pulls uke onto tori's upper leg, tori stretches it out and raises it up. Then, to complete the toss, bounce the uke up and continue to turn and roll forward.

### **Figure 28**

*Execution of Uchi-Mata (Inner Thigh Throw)*



### **Ouchi Gari (OUG) – Major Inner Reap**

Reap uke's left leg from the inside with tori's right leg after breaking his balance to his left back corner, causing him to fall backward.

Phase I : Get into a good natural posture. Take a little step forward with tori's left foot, raise and draw back tori's right foot a bit, and with tori's right hand, pull uke toward his left front corner.

Phase II : Uke will step forward with his left foot. Slip tori's right leg in behind his left leg just before he sets his foot down, bringing the back of your knee up against the back of his left knee.

Phase III : Clip the leg over tori's right back corner in a large area.

Phase IV : Using both hands, push the uke straight down.

#### **Figure 29**

*Execution of O-Uchi-Gari (Major Inner Reap)*



### Selection of Weight Categories

The following weight categories were utilized in the All India Inter University Championships and World University Competitions held under the auspices of the AIIU, JFI and IJF were chosen as the independent variables.

**Table 3**

*Selected Weight Categories*

Sl No.	Weight Category	Weight Classes	
1.	Below 60	Extra Light Weight	Up to and including 60.0 kg
2.	Below 66	Half Light Weight	Over 60.0 kg up to and including 66.0 kg
3.	Below 73	Light Weight	Over 66.0 kg up to and including 73.0 kg
4.	Below 81	Half Middle Weight	Over 73.0 kg up to and including 81.0 kg
5.	Below 90	Middle Weight	Over 81.0 kg up to and including 90.0 kg
6.	Below 100	Half Heavy Weight	Over 90.0 kg up to and including 100.0 kg
7.	Above 100	Heavy Weight	Over 100.0 kg

Source: SOR, International Judo Federation, 2023

### Selection of Experimental Equipment

The investigator used the following standard equipment to collect primary data in order to achieve the study's objectives.

#### Video Camera 1

Sony PXW-FS5 XDCAM Super 35 Camera System Professional Camcorder, Black (PXWFS5), 240fps HFR in Full HD and 240fps HFR in 4K with FS RAW output with optional CBKZ-FS5RIF upgrade kit, were used to record the execution of the selected techniques.

**Figure 30**

*Video Camera I*



**Video Camera 2**

VarioCAM® HD inspect 800 were used as the second camera which supports IR and Efficient measurement of smallest structures on large-scale objects, Full-frame: 30 Hz (1,024 × 768), sub-frame formats\*: 60 Hz (640 × 480) / 120 Hz (384 × 288) / 240 Hz (1,024 × 96)

**Figure 31**

*Video Camera II*



## Tripods

Stable Tripod: Made of aluminium alloy, the tripod with maximum 1.1"/28mm tube diameter is stable enough to support your camera gear up to

33lb/15kg. Comes with a carabiner which can hang sandbag or other heavy objects to increase stability if necessary.

### **Tatami**

Tatami were (a type of mat) used as a flooring material in the platform where the judokas performed the selected techniques. Tatamis are made in standard sizes, twice as long as wide, about 1 m X 2 m. (see Appendix C).

### **Calibration Indicator**

The reference axes were fixed bodies positioned in the camera's field of view. A metal rod of length 2m were used to calibrate axis and the colour of the contest mat area for calibration and was filmed in the plane of motion.

### **Lap tops and hard disk**

Apple MacBook Pro and Seagate Backup Plus Slim 1 TB hard disk was used to save the footage with different file name for each weight category for all Throwing Technique.

## **Reliability of the Data**

All of the instruments and equipment were guaranteed to meet international standards and their accuracy by the vendors. As a result, the data acquired with these devices and equipment was deemed reliable for the study's purposes.

## **Motion Capture Protocol**

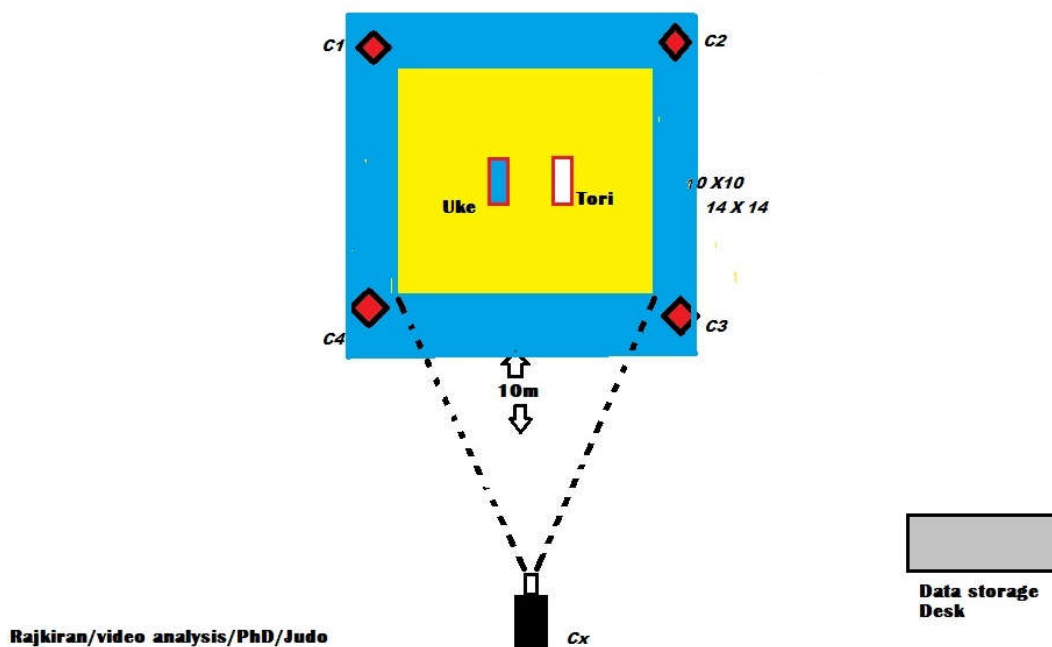
Motion capture technology was employed to accurately record the movements and joint angles of judo practitioners executing the selected techniques. This technology provides precise data on angular velocity, angular displacement, and the position of the center of gravity, as well as the angle of the hip and knee joints during the execution of each technique. The use of motion capture technology ensures that the biomechanical analysis is based on objective and quantifiable data, allowing for a thorough examination of the mechanics and principles governing the effectiveness of each technique.

For video recording, a 16mm camera (Sony high definition or 240f/s) was positioned at a distance of 10 meters from the centre of the contest (Technique Performing) area. The throwing area was 10X10 meters and was covered with tatami, a type of Judo mat. The camera was fixed on a tripod and angled at a right angle to the performer's (sagittal plane) plane of movement. The reference axes were fixed bodies positioned in the camera's field of view. The colour of the contest mat area for calibration and was filmed in the plane of motion.

The frame rate of the high definition camera was set at 240 frames per second. Videos of selected Judo Techniques were recorded and examined in the Biomechanics software tool. The experiment was conducted using an experimental approach before the competition, and camera operators were well informed. This guaranteed that data was collected in a consistent manner was the test competency.

### Figure 32

*Video Capture Set Up as per Rules and Regulations of IJF (International Judo Federation)*



To achieve ideal visual creation, camera setup with a 10 x 10 m viewing volume was used. This viewing volume is large enough to record subject performance.

This tool does not require the use of any markers. The camera guy employed under the supervision of scholar to capture the performance of each bout scheduled in the fixture, after which the Referee calls “Hjime” began to capture the bouts and continued until the throwing technique was completed or by the “mate” call by the Referee. The footage was saved on an external hard disc with a different file name for each weight category for each Throwing Technique. The scholar also collected secondary data of the performance of selected throwing techniques from the available sources.

### Optimisation and detailing of video samples

By considering the nature of complexity in the acquisition of data during the execution of Judo techniques in real time, optimisation of values may or may not be approximately closer to the accuracy. The researcher collected and observed videos of actual application of the selected techniques from the All India inter university championship detailed in Appendix B. The researcher availed primary as well as secondary resources to observe and collect the relevant videos of technique performance.

### Figure 33

#### *Landmark Placement*



M1: Acromion; M2: Greater trochanter; M3: Lateral Epicondyle of the Femur; M4: Lateral Malleolus.  
 Angle of Hip Flexion: Angle Between M1M2 and M2M3  
 Angle of Knee Flexion: Angle between M2M3 and M3M4

### Collection of Data

The data were acquired through video analysis of footage capturing the performance of judo techniques. Motion capture analysis was used to quantify the kinematic variables. Values were obtained by employing Quintic video Software and Kinovea software (Deepak Dhaka, Reena Huda, 2019). Quintic video software is a very powerful analysis tool. The software enables the scholar to detail video images via the computer screen. The scholar used various methods such as Angular analysis, Distance measurement function, Drawing tool-Lines, shapes, angles and text, Single image capture(jpeg), Split screen and synchronization, Interactive graph and data displays, Zoom tool, Digitalization module, Expert Avi function, Expert analysis, with the soft wares to obtain kinematic scores. The obtained data from video analysis were exported to an Excel spreadsheet.

Observation of Kinematical properties of the selected techniques performed by the Tori (those who applied the throwing technique) in each weight categories were obtained on the basis of angular motion of Uke (those who receives throw) which involves from the end phase of Tsukuri to the end Phase of Kake performed by Tori.

### Statistics

The collected data has been undergone statistical tests, Box's M test was used to check the equality of multiple variance-covariance matrices, as a result it was obvious that the hypothesis has to be retained and Pillai's trace test produced by a MANOVA was fit to find the significance among the collected data, so that the analysis of data had done by tabulating the data and applying Two-way MANOVA (analysis of Multivariate) to understand and interpret the objectives inline of the findings. The Two-way ANOVA was employed to see if there are any significant differences in a dependent variable between two or more independent groups (Weight categories and Judo techniques).

Post Hoc test were administrated for the critical interpretation on kinematical variables in the application of selected judo techniques. All the statistical

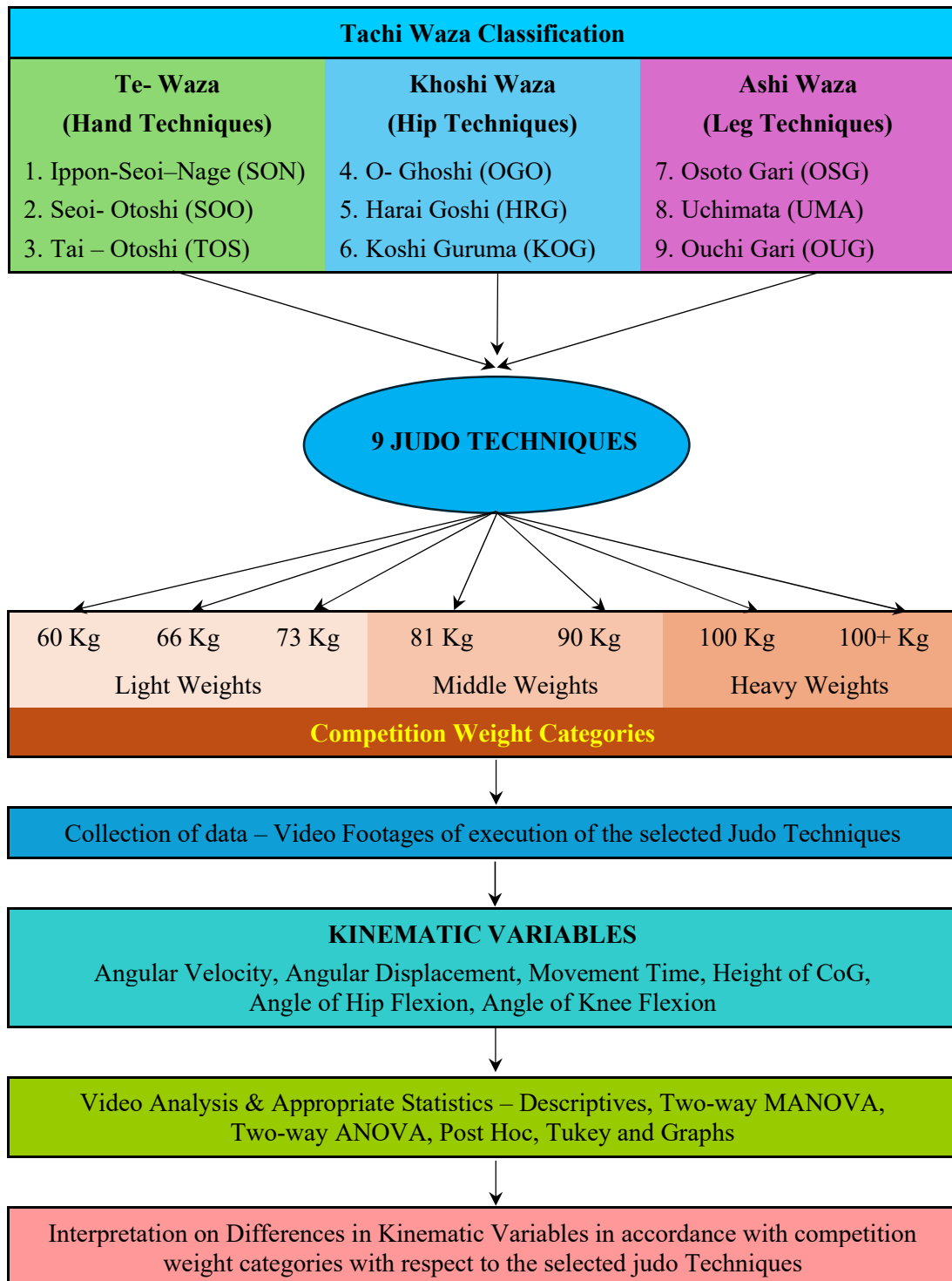
computations had been done with the SPSS version 23.0.1 software by IBM.

### **Level of significance**

The level of significance chosen was 0.05 throughout the study to ascertain the significant relationship between the independent variables selected techniques and dependent variables selected judo techniques with weight categories. These significant levels were considered adequate for the purpose of this study.

The scholar started the analysis with the comparison of kinematical variables among selected techniques and different weight categories.

**Research Design**



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Chapter IV  
**ANALYSIS OF DATA AND  
THE RESULTS OF THE STUDY**

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Analysis of Data .....	108
Analysis of Kinematic Variables.....	110
Findings of the Study .....	184
Discussion of Findings.....	202
Discussion of the Hypotheses.....	206

In this chapter the analysis of data, findings of the study and discussion of findings had been described. The goal of researcher was to determine the importance of specific kinematical characteristics and its precedence on selected judo techniques in relation to competitive weight categories; hence discover the Kinematical profile of the selected judo techniques, explore the kinematical advantages of the selected judo techniques, quantify the kinematics of each weight categories related to the selected Judo techniques, explore the difference of kinematical advantages in the selected judo techniques, document the kinematical characteristics of the selected judo techniques, compare of selected kinematical variables among different weight categories and to discover the techniques which have more kinematical advantages according to the weight category were the objectives of the study.

To meet the objectives of the study nine judo techniques listed in the Table 5 which are frequently used by the judokas in the international championships like Olympics, Grandprix , World judo championship etc. similarly the selected techniques were dominated in the All India Inter University Championships and six kinematical variables namely Angular Velocity, Angular Displacement, Movement time, Height of CoG , Angle of Hip joint, Angle of knee flexion, , were selected to compare the kinematical influences among different weight categories. The kinematical data were obtained by using video analysis of the selected techniques performed by the judokas in All India Inter University Judo Championships. The data obtained from video analysis were exported to Microsoft excel file for analysis.

### Analysis of Data

Analysis of data had done by tabulating the data and developing different graphs to understand and interpret the objectives inline of the findings. For the economy of documentation, the measures from the recorded videos of the judo techniques applied in the all India Inter university championship the selected variables and techniques had been abbreviated and documented in Table 4, 5 and 6.

**Table 4**

*Abbreviations of selected Kinematic Variables*

SI No.	Dependent Variables	Code	Criterion
1.	Angular Velocity	( $\Delta V$ )	rad/sec
2.	Angular Displacement	( $\Delta D$ )	rad
3.	Movement Time	( $\Delta T$ )	sec
4.	Height of CoG	(HCG)	cm
5.	Angle of Hip Flexion	(AHJ)	deg
6.	Angle of knee flexion	(AKJ)	deg

**Table 5**

*Abbreviations of selected Independent Variables*

SI No.	Judo Techniques	Code	Tachi Waza Classification
1.	Ippon-Seoi-Nage	(SON)	<b>Te Waza</b> (Hand Techniques)
2.	Seoi – Otoshi	(SOO)	
3.	Tai – Otoshi	(TOS)	
4.	O- Ghoshi	(OGO)	<b>Koshi Waza</b> (Hip Techniques)
5.	Harai Goshi	(HRG)	
6.	Koshi Guruma	(KOG)	
7.	Osoto Gari	(OSG)	<b>Ashi Waza</b> (Leg Techniques)
8.	Uchimata	(UMA)	
9.	Ouchi Gari	(OUG)	

**Table 6***Classification of Competition Weight Categories*

SI No.	Weight Category	Weight Classification
1.	Below 60	Up to and including 60.0 kg
2.	Below 66	<b>Light Weights</b>
3.	Below 73	
4.	Below 81	
5.	Below 90	<b>Middle Weight</b>
6.	Below 100	<b>Heavy Weight</b>
7.	Above 100	

Source: SOR, International Judo federation 2023

The obtained data was subjected to statistical tests; the equality of multiple variance-covariance matrices was checked using Box's M test, which made it clear that the hypothesis had to be retained. The significance of data was determined using Pillai's trace test, which was generated by a MANOVA; thus, the data was tabulated and Two-way MANOVA (analysis of multivariate) was used to understand and interpret the objectives in accordance with the findings. To determine whether there are any noteworthy variations in a dependent variable (weight categories and judo techniques) between two or more independent groups, a two-way ANOVA was employed separately. In order to critically analyze kinematical primacy in the execution of particular judo techniques, post-hoc tests were administered. IBM's SPSS version 23.0.1 software has been employed for all statistical calculations.

### **Level of significance**

The level of significance chosen was 0.05 throughout the study to ascertain the significant relationship between the independent variables selected techniques and dependent variables selected judo techniques with weight categories. These significant levels were considered adequate for the purpose of this study.

The scholar started the analysis with the comparison of kinematical variables among selected techniques and different weight categories.

### **Analysis of Kinematic Variables**

To meet the objectives that were outlined for the research, statistical analysis of the kinematic variables has been carried out in three distinct steps.

Step I: The competition weight categories were classified in to light weight, middle weight and heavy weight to analyse each of the chosen kinematic variables.

Step II: The chosen judo techniques Nage Waza (Throwing Techniques) were categorized into Tachi Waza namely, Te Waza, Koshi Waza and Ashi Waza are Hand Techniques, Hip Techniques and Leg Techniques respectively in order to further analyse the kinematic variables in accordance with the competition weight categories. Subsequently, Analysis was done for each selected judo techniques. Tukey's post Hoc test were employed.

Step III: Univariate Analyses were done to examine the interaction between weight categories and selected judo techniques on kinematic variables.

Two way ANOVA followed by Tukey's Post Hoc test were applied and Clustered Bar diagrams were employed to the mean comparison and for the illustration of interaction between weight categories and selected judo techniques on kinematic variables

**Analysis of Kinematic Variables in accordance with competition Weight Categories corresponding to the selected Judo Techniques**

Two-way MANOVA was done for which statistical hypothesis was framed as:

*H<sub>01</sub>: There is no significant difference in kinematic variables in accordance with competition weight categories*

*H<sub>02</sub>: There is no significant difference in kinematic variables in accordance with selected Judo Techniques*

*H<sub>03</sub>: There is no significant interaction on kinematic variables in between the weight categories and selected Judo Techniques*

To meet the objective of the study Competition weight categories has been classified as Light Weights (-60 Kg, -66 Kg & -73 Kg), Middle weights (-81Kg & -90 Kg) and Heavy Weights (-100 Kg & +100 Kg) accordingly.

**Table 7***Descriptives of the Kinematic Variables in accordance with weight categories*

Weight/Category		Dependent Variables					
		Angular Velocity	Angular Displacement	Movement Time	Height of CoG	Angle of Hip Joint	Angle of Knee Joint
<b>Light Weights</b>	Mean	1.095	4.272	4.089	0.714	106.415	105.682
	N	135	135	135	135	135	135
	Skewness	0.598	-0.398	-0.142	-0.452	0.311	0.034
	Kurtosis	-1.044	-1.120	-1.280	-0.802	-1.590	-1.403
	Std. Deviation	0.290	0.373	0.760	0.046	37.880	39.162
<b>Middle Weights</b>	Mean	0.911	4.236	4.750	0.859	115.800	126.900
	N	90	90	90	90	90	90
	Skewness	-0.070	-0.669	0.470	-3.264	0.549	-0.155
	Kurtosis	-1.100	-0.061	-0.915	22.683	-1.465	-1.217
	Std. Deviation	0.142	0.279	0.716	0.047	39.427	35.636
<b>Heavy Weights</b>	Mean	0.788	4.742	6.178	0.929	132.633	145.744
	N	90	90	90	90	90	90
	Skewness	1.445	-0.329	-0.827	-0.171	0.245	-0.340
	Kurtosis	1.892	-0.961	-0.130	-0.824	-1.693	-1.333
	Std. Deviation	0.143	0.116	0.889	0.021	37.209	31.189

<b>Weight/Category</b>		<b>Dependent Variables</b>					
		<b>Angular Velocity</b>	<b>Angular Displacement</b>	<b>Movement Time</b>	<b>Height of CoG</b>	<b>Angle of Hip Joint</b>	<b>Angle of Knee Joint</b>
<b>Total</b>	Mean	0.955	4.396	4.875	0.817	116.587	123.191
	N	315	315	315	315	315	315
	Skewness	1.141	-0.653	0.330	-0.296	0.322	-0.237
	Kurtosis	0.645	-0.567	-0.698	-1.145	-1.393	-1.093
	Std. Deviation	0.254	0.365	1.171	0.101	39.546	39.645

The means and standard deviation of dependent variables in the execution of selected judo techniques in accordance with the weight categories have been shown in Table 7 and it is found that the mean score is different in different weight categories.

**Table 8***Box's Test of Equality of Covariance Matrices*

Box's M	2791.218
F	6.808
df1	315
df2	15334.687
Sig.	.000

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

As per Box's M test [ Box's M = 2791.218,  $F(315,15334.687) = 6.808$ ,  $P < .001$ ]. Hence a two-way MANOVA was conducted to analyze the effects of weight categories and selected judo Techniques on kinematic variables, Pillai's Trace Test has been employed in the context of the violation of the equality of covariance matrices.

**Table 9**

*Two- way Multivariate Analysis of kinematic variables in accordance with weight categories corresponding to the selected judo techniques*

	Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	1.000	343643.311	6.000	283.000	.000	1.000
	Wilks' Lambda	.000	343643.311	6.000	283.000	.000	1.000
	Hotelling's Trace	7285.724	343643.311	6.000	283.000	.000	1.000
	Roy's Largest Root	7285.724	343643.311	6.000	283.000	.000	1.000
Weight Categories	Pillai's Trace	1.667	236.527	12.000	568.000	.000	.833
	Wilks' Lambda	.005	625.482	12.000	566.000	.000	.930
	Hotelling's Trace	65.826	1546.918	12.000	564.000	.000	.971
	Roy's Largest Root	63.682	3014.283	6.000	284.000	.000	.985
Judo Techniques	Pillai's Trace	2.862	32.835	48.000	1728.000	.000	.477
	Wilks' Lambda	.000	140.924	48.000	1396.541	.000	.765
	Hotelling's Trace	143.734	842.442	48.000	1688.000	.000	.960
	Roy's Largest Root	129.993	4679.746	8.000	288.000	.000	.992
Weight Categories * Judo Techniques	Pillai's Trace	3.105	19.302	96.000	1728.000	.000	.517
	Wilks' Lambda	.006	24.708	96.000	1610.150	.000	.575
	Hotelling's Trace	10.803	31.658	96.000	1688.000	.000	.643
	Roy's Largest Root	5.869	105.636	16.000	288.000	.000	.854

The results of MANOVA were presented in the Table 7 It reveals that, the calculated Pillai's trace F value of Weight Categories was 236.527, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{01}$  for weight categories (Between Groups) were failed to accept. The calculated Pillai's trace F value of selected judo techniques was 32.835, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{02}$  for weight categories (Between Groups) were failed to accept. The statistical results shows that there is a significant interaction between competition weight categories and selected judo techniques with Pillai's trace F value 19.302 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical hypothesis  $H_{03}$  for weight categories (Between Groups) were failed to accept.*

A Pair wise comparison has been done to explain significant difference among weight categories by using Least Significant Difference, LSD test (Post hoc test).

**Table 10**

*Tukey's Post Hoc test for Kinematic Variables in accordance with weight categories*

Dependent Variable	(I) Weight Categories	(J) Weight Categories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Angular Velocity	Light Weights	Middle Weights	.1845*	.01293	.000	.1541	.2150
		Heavy Weights	.3078*	.01293	.000	.2773	.3382
	Middle Weights	Light Weights	-.1845*	.01293	.000	-.2150	-.1541
		Heavy Weights	.1233*	.01416	.000	.0899	.1566
	Heavy Weights	Light Weights	-.3078*	.01293	.000	-.3382	-.2773
		Middle Weights	-.1233*	.01416	.000	-.1566	-.0899

Dependent Variable	(I) Weight Categories	(J) Weight Categories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Angular Displacement	Light Weights	Middle Weights	.0357	.01972	.168	-.0108	.0821	
		Heavy Weights	-.4704*	.01972	.000	-.5169	-.4240	
	Middle Weights	Light Weights	-.0357	.01972	.168	-.0821	.0108	
		Heavy Weights	-.5061*	.02160	.000	-.5570	-.4552	
	Heavy Weights	Light Weights	.4704*	.01972	.000	.4240	.5169	
		Middle Weights	.5061*	.02160	.000	.4552	.5570	
	Movement Time	Light Weights	Middle Weights	-.6611*	.04986	.000	-.7786	-.5437
			Heavy Weights	-2.0889*	.04986	.000	-2.2063	-1.9714
Middle Weights		Light Weights	.6611*	.04986	.000	.5437	.7786	
		Heavy Weights	-1.4278*	.05462	.000	-1.5564	-1.2991	
Heavy Weights		Light Weights	2.0889*	.04986	.000	1.9714	2.2063	
		Middle Weights	1.4278*	.05462	.000	1.2991	1.5564	
Height of CoG		Light Weights	Middle Weights	-.1451*	.00318	.000	-.1526	-.1376
			Heavy Weights	-.2146*	.00318	.000	-.2221	-.2071
	Middle Weights	Light Weights	.1451*	.00318	.000	.1376	.1526	
		Heavy Weights	-.0696*	.00349	.000	-.0778	-.0613	
	Heavy Weights	Light Weights	.2146*	.00318	.000	.2071	.2221	
		Middle Weights	.0696*	.00349	.000	.0613	.0778	
	Angle of Hip Joint	Light Weights	Middle Weights	-9.3852*	1.18252	.000	-12.1711	-6.5993
			Heavy Weights	-26.2185*	1.18252	.000	-29.0044	-23.4326
Middle Weights		Light Weights	9.3852*	1.18252	.000	6.5993	12.1711	
		Heavy Weights	-16.8333*	1.29539	.000	-19.8851	-13.7815	
Heavy Weights		Light Weights	26.2185*	1.18252	.000	23.4326	29.0044	
		Middle Weights	16.8333*	1.29539	.000	13.7815	19.8851	
Angle of knee flexion		Light Weights	Middle Weights	-21.2185*	.45342	.000	-22.2867	-20.1503
			Heavy Weights	-40.0630*	.45342	.000	-41.1312	-38.9947
	Middle Weights	Light Weights	21.2185*	.45342	.000	20.1503	22.2867	
		Heavy Weights	-18.8444*	.49670	.000	-20.0146	-17.6743	
	Heavy Weights	Light Weights	40.0630*	.45342	.000	38.9947	41.1312	
		Middle Weights	18.8444*	.49670	.000	17.6743	20.0146	

\*. The mean difference is significant at the .05 level.

As the statistical results revealed that there is significant difference, further analysis is needed to explain which level of category makes the difference. Tukey's Post Hoc analysis is used to explain the difference. The result of the analysis is shown in the Table 10 which shows the Tukey's Post Hoc result for the kinematic variables among three weight categories.

For the Angular Velocity, It was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angular Displacement among three weight categories. It was observed that there is no significant difference between 'Light weights' and 'Middle weights' (.168), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and Middle weights' and 'Heavy weights' (.001).

For the Movement Time, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Height of CoG, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angle of Hip Flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

**Analysis of kinematic variables in accordance with Competition weight categories corresponding to Tachi Waza classification of selected Judo Techniques**

Two-way MANOVA was done for which hypothesis was framed as:

*H<sub>04</sub>: There is no significant difference in Kinematic Variables among competition weight categories corresponding to the Tachi Waza classification of judo techniques.*

*H<sub>05</sub>: There is no significant difference in Kinematic Variables among the Tachi Waza classification of Judo techniques, Te Waza, Koshi Waza & Ashi Waza respectively accordance with weight categories.*

*H<sub>06</sub>: There is no significant interaction on kinematic variables in between the weight categories and Tachi Waza classification of Judo Techniques*

**Table 11**

*Descriptives of kinematic variables corresponding to the Tachi Waza classification of Judo Techniques accordance with the weight categories*

Weight Categories		Angular Velocity	Angular Displacement	Movement Time	Height of C. G	Angle of Hip Joint	Angle of knee flexion	
Light Weights	Te Waza (Hand Techniques)	Mean	1.450	4.637	3.244	0.706	103.289	64.578
		N	45	45	45	45	45	45
		Skewness	-1.007	-0.605	1.307	-0.623	0.732	0.296
		Kurtosis	-0.689	0.453	-0.207	-1.425	-1.500	-1.359
		Std. Deviation	0.170	0.114	0.413	0.046	29.355	16.780
	Koshi Waza (Hip Techniques)	Mean	0.872	3.829	4.444	0.695	88.311	106.667
		N	45	45	45	45	45	45
		Skewness	-0.295	0.691	0.231	-0.206	0.594	0.715
		Kurtosis	-1.562	0.052	-2.039	-1.255	-1.379	-1.479
		Std. Deviation	0.103	0.192	0.503	0.043	27.575	27.536
	Ashi Waza (Leg Techniques)	Mean	0.964	4.350	4.578	0.741	127.644	145.800
		N	45	45	45	45	45	45
		Skewness	0.292	0.204	-0.274	-0.096	-0.695	-0.699
		Kurtosis	-1.856	-1.206	-1.966	-1.399	-1.507	-1.260
		Std. Deviation	0.138	0.172	0.481	0.034	44.066	15.995
	Total	Mean	1.095	4.272	4.089	0.714	106.415	105.681
N		135	135	135	135	135	135	
Skewness		0.598	-0.398	-0.142	-0.452	0.311	0.034	
Kurtosis		-1.044	-1.120	-1.280	-0.802	-1.590	-1.403	
Std. Deviation		0.290	0.373	0.760	0.046	37.880	39.162	

Weight Categories		Angular Velocity	Angular Displacement	Movement Time	Height of C. G	Angle of Hip Joint	Angle of knee flexion	
Middle Weights	Te Waza (Hand Techniques)	Mean	0.809	4.398	5.500	0.853	107.567	94.000
		N	30	30	30	30	30	30
		Skewness	0.016	0.071	0.000	1.256	0.732	0.032
		Kurtosis	-2.097	-1.735	-2.148	1.040	-1.521	-1.463
		Std. Deviation	0.110	0.201	0.509	0.030	39.488	23.309
	Koshi Waza (Hip Techniques)	Mean	0.984	4.296	4.417	0.837	104.633	122.933
		N	30	30	30	30	30	30
		Skewness	-0.193	0.480	0.351	-4.314	0.582	0.583
		Kurtosis	-1.618	-0.024	-1.764	21.573	-1.492	-1.527
		Std. Deviation	0.113	0.116	0.456	0.060	25.527	25.649
	Ashi Waza (Leg Techniques)	Mean	0.939	4.015	4.333	0.887	135.200	163.767
		N	30	30	30	30	30	30
		Skewness	-0.190	0.276	0.745	-0.301	-0.123	-0.651
		Kurtosis	-1.162	-1.382	-1.554	-0.192	-2.082	-1.348
		Std. Deviation	0.140	0.321	0.479	0.031	44.398	12.417
	Total	Mean	0.911	4.236	4.750	0.859	115.800	126.900
N		30	30	30	30	30	30	
Skewness		-0.070	-0.669	0.470	-3.264	0.549	-0.155	
Kurtosis		-1.100	-0.061	-0.915	22.683	-1.465	-1.217	
Std. Deviation		0.142	0.279	0.716	0.047	39.427	35.636	

Weight Categories		Angular Velocity	Angular Displacement	Movement Time	Height of C. G	Angle of Hip Joint	Angle of knee flexion	
Heavy Weights	Te Waza (Hand Techniques)	Mean	0.681	4.641	6.833	0.930	122.333	118.200
		N	30	30	30	30	30	30
		Skewness	1.500	0.479	-1.884	0.096	0.774	0.285
		Kurtosis	0.942	-0.741	1.657	-0.899	-1.453	-1.398
		Std. Deviation	0.037	0.094	0.379	0.023	44.800	23.535
	Koshi Waza (Hip Techniques)	Mean	0.742	4.794	6.500	0.922	121.133	143.100
		N	30	30	30	30	30	30
		Skewness	0.003	-0.420	0.000	0.083	0.726	0.497
		Kurtosis	-2.075	-0.025	-2.148	-1.146	-1.322	-1.495
		Std. Deviation	0.063	0.059	0.509	0.023	25.507	26.008
	Ashi Waza (Leg Techniques)	Mean	0.939	4.791	5.200	0.934	154.433	175.933
		N	30	30	30	30	30	30
		Skewness	0.875	-0.587	-0.397	-0.656	-0.762	-0.756
		Kurtosis	-0.063	-0.936	-0.702	-0.046	-1.403	-0.270
		Std. Deviation	0.141	0.114	0.695	0.016	29.210	4.495
	Total	Mean	0.788	4.742	6.178	0.929	132.633	145.744
	N	90	90	90	90	90	90	
	Skewness	1.445	-0.329	-0.827	-0.171	0.245	-0.340	
	Kurtosis	1.892	-0.961	-0.130	-0.824	-1.693	-1.333	
	Std. Deviation	0.143	0.116	0.889	0.021	37.209	31.189	

Weight Categories		Angular Velocity	Angular Displacement	Movement Time	Height of C. G	Angle of Hip Joint	Angle of knee flexion
Total	Mean	1.047	4.570	4.914	0.812	109.952	88.305
	Te Waza (Hand Techniques)	N	105	105	105	105	105
	Skewness	0.388	-1.020	0.022	-0.225	0.913	0.412
	Kurtosis	-1.577	0.381	-1.597	-1.194	-0.784	-0.661
	Std. Deviation	0.376	0.177	1.598	0.103	37.737	30.591
	Mean	0.867	4.238	5.024	0.801	102.352	121.724
	Koshi Waza (Hip Techniques)	N	105	105	105	105	105
	Skewness	0.262	0.068	0.714	-0.256	0.368	0.381
	Kurtosis	-0.967	-1.321	-0.749	-1.180	-0.919	-1.077
	Std. Deviation	0.133	0.428	1.057	0.107	29.553	30.384
	Mean	0.950	4.380	4.686	0.838	137.457	159.543
	Ashi Waza (Leg Techniques)	N	105	105	105	105	105
	Skewness	0.309	-0.417	0.417	-0.256	-0.657	-0.880
	Kurtosis	-1.144	-0.573	-0.723	-1.513	-1.200	-0.133
	Std. Deviation	0.139	0.364	0.643	0.091	41.658	17.923
	Mean	0.955	4.396	4.875	0.817	116.587	123.190
Total	N	315	315	315	315	315	
Skewness	1.141	-0.653	0.330	-0.296	0.322	-0.237	
Kurtosis	0.645	-0.567	-0.698	-1.145	-1.393	-1.093	
Std. Deviation	0.254	0.365	1.171	0.101	39.546	39.645	

The means and standard deviation of kinematic variables in the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in Table 11 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories.

**Table 12**

*Box's Test of Equality of Covariance Matrices*

Box's M	3058.814
F	16.860
df1	168
df2	83166.157
Sig.	.000

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

As per Box's M test [ Box's M = 3058.814, F(168,83166.157) = 16.860, P < .001] , Hence a two-way MANOVA was conducted to analyze the effects of weight categories and Tachi Waza classification selected judo Techniques on kinematic variables, Pillai's Trace Test has been employed in the context of the violation of the equality of covariance matrices.

**Table 13**

*Two- way Multivariate Analysis (MANOVA) of kinematic variables in accordance with weight categories corresponding to the classification of selected Judo Techniques*

Effect	Value	F	Hypothesis df	Error df	Sig.	
Pillai's Trace	1.000	126993.452	6.000	301.000	.000	
Wilks' Lambda	.000	126993.452	6.000	301.000	.000	
Intercept	Hotelling's Trace	2531.431	126993.452	6.000	301.000	.000
	Roy's Largest Root	2531.431	126993.452	6.000	301.000	.000

	Effect	Value	F	Hypothesis df	Error df	Sig.
Weight Category	Pillai's Trace	1.559	178.114	12.000	604.000	.000
	Wilks' Lambda	.024	272.642	12.000	602.000	.000
	Hotelling's Trace	16.246	406.141	12.000	600.000	.000
	Roy's Largest Root	14.590	734.346	6.000	302.000	.000
Tachi Waza Classification	Pillai's Trace	1.055	56.138	12.000	604.000	.000
	Wilks' Lambda	.160	75.246	12.000	602.000	.000
	Hotelling's Trace	3.909	97.721	12.000	600.000	.000
	Roy's Largest Root	3.529	177.623	6.000	302.000	.000
Weight Categories * Tachi Waza Classification	Pillai's Trace	1.508	30.659	24.000	1216.000	.000
	Wilks' Lambda	.100	40.883	24.000	1051.274	.000
	Hotelling's Trace	3.876	48.364	24.000	1198.000	.000
	Roy's Largest Root	2.174	110.170 <sup>c</sup>	6.000	304.000	.000

The results of MANOVA were presented in the Table 13 It reveals that, the calculated Pillai's trace F value of Weight Categories was 178.114, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{04}$  for weight categories (Between Groups) were failed to accept. The calculated Pillai's trace F value of classification of selected judo techniques was 56.138, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{05}$  for Tachi Waza classification of judo techniques (Between Groups) were failed to accept. The statistical results shows that there is a significant interaction between competition weight categories and classification selected judo techniques with Pillai's trace F value 30.695 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{06}$  for the interaction between weight categories and Tachi Waza classification of judo techniques (Between Groups) were failed to accept.

A Pair wise comparison has been done to explain significant difference among classified Judo Techniques by using Least Significant Difference, LSD test (Post hoc test).

**Table 14**

*Tukey's Post Hoc test for Kinematic Variables in accordance with Weight categories corresponding to the Tachi Waza classification of judo Techniques.*

Dependent Variable	(I) Weight Categories	(J) Weight Categories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Angular Velocity	Light Weights	Middle Weights	.1845*	.01671	.000	.1452	.2239
		Heavy Weights	.3078*	.01671	.000	.2684	.3471
	Middle Weights	Light Weights	-.1845*	.01671	.000	-.2239	-.1452
		Heavy Weights	.1233*	.01831	.000	.0801	.1664
	Heavy Weights	Light Weights	-.3078*	.01671	.000	-.3471	-.2684
		Middle Weights	-.1233*	.01831	.000	-.1664	-.0801
Angular Displacement	Light Weights	Middle Weights	.0357	.02306	.271	-.0186	.0900
		Heavy Weights	-.4704*	.02306	.000	-.5247	-.4161
	Middle Weights	Light Weights	-.0357	.02306	.271	-.0900	.0186
		Heavy Weights	-.5061*	.02526	.000	-.5656	-.4466
	Heavy Weights	Light Weights	.4704*	.02306	.000	.4161	.5247
		Middle Weights	.5061*	.02526	.000	.4466	.5656

Dependent Variable	(I) Weight Categories	(J) Weight Categories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Movement Time	Light Weights	Middle Weights	-.6611*	.06722	.000	-.8194	-.5028
		Heavy Weights	-2.0889*	.06722	.000	-2.2472	-1.9306
	Middle Weights	Light Weights	.6611*	.06722	.000	.5028	.8194
		Heavy Weights	-1.4278*	.07364	.000	-1.6012	-1.2543
	Heavy Weights	Light Weights	2.0889*	.06722	.000	1.9306	2.2472
		Middle Weights	1.4278*	.07364	.000	1.2543	1.6012
Height CoG	Light Weights	Middle Weights	-.1451*	.00506	.000	-.1570	-.1331
		Heavy Weights	-.2146*	.00506	.000	-.2265	-.2027
	Middle Weights	Light Weights	.1451*	.00506	.000	.1331	.1570
		Heavy Weights	-.0696*	.00555	.000	-.0826	-.0565
	Heavy Weights	Light Weights	.2146*	.00506	.000	.2027	.2265
		Middle Weights	.0696*	.00555	.000	.0565	.0826
Angle of Hip Joint	Light Weights	Middle Weights	-9.3852	4.79492	.125	-20.6781	1.9077
		Heavy Weights	-26.2185*	4.79492	.000	-37.5114	-14.9256
	Middle Weights	Light Weights	9.3852	4.79492	.125	-1.9077	20.6781
		Heavy Weights	-16.8333*	5.25257	.004	-29.2041	-4.4626
	Heavy Weights	Light Weights	26.2185*	4.79492	.000	14.9256	37.5114
		Middle Weights	16.8333*	5.25257	.004	4.4626	29.2041

Dependent Variable	(I) Weight Categories	(J) Weight Categories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Angle of knee flexion	Light Weights	Middle Weights	-21.2185*	2.83256	.000	-27.8897	14.5473
		Heavy Weights	-40.0630*	2.83256	.000	-46.7341	33.3918
	Middle Weights	Light Weights	21.2185*	2.83256	.000	14.5473	27.8897
		Heavy Weights	-18.8444*	3.10292	.000	-26.1524	11.5365
	Heavy Weights	Light Weights	40.0630*	2.83256	.000	33.3918	46.7341
		Middle Weights	18.8444*	3.10292	.000	11.5365	26.1524

\*. The mean difference is significant at the .05 level.

The result of the analysis is shown in the Table 14, which shows the Tukey's Post Hoc result for the kinematic variables among three weight categories corresponding to the Tachi Waza Classification of Judo Techniques.

For the Angular Velocity, It was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weight' and 'Heavy weight' (.001), and "Middle weights' and Heavy weights' (.001).

For the Angular Displacement among three weight categories. It was observed that there is no significant difference between 'Light weights' and 'Middle weights' (.271), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and "Middle weights' and "Heavy weights' (.001).

For the Movement Time, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and "Middle weights' and Heavy weights' (.001).

For the Height of CoG, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and Middle weights' and Heavy weights' (.001).

For the Angle of Hip flexion, it was observed that there is no significant difference between 'Light weights' and 'Middle weights' (.125), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and Heavy weights' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and Heavy weights' (.001).

**Table 15**

*Tukey's Post Hoc test for Kinematic Variables in accordance with Tachi Waza classification of Judo Techniques*

Dependent Variable	(I) TACHI WAZA classification of Techniques	(J) TACHI WAZA classification of Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Angular Velocity	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	.1804*	.01695	.000	.1404	.2203
		Ashi Waza (Leg Techniques)	.0972*	.01695	.000	.0573	.1371
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	-.1804*	.01695	.000	-.2203	-.1404
		Ashi Waza (Leg Techniques)	-.0832*	.01695	.000	-.1231	-.0433
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	-.0972*	.01695	.000	-.1371	-.0573
		Koshi Waza (Hip Techniques)	.0832*	.01695	.000	.0433	.1231
Angular Displacement	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	.3318*	.02339	.000	.2767	.3869
		Ashi Waza (Leg Techniques)	.1896*	.02339	.000	.1345	.2446
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	-.3318*	.02339	.000	-.3869	-.2767
		Ashi Waza (Leg Techniques)	-.1422*	.02339	.000	-.1973	-.0871
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	-.1896*	.02339	.000	-.2446	-.1345
		Koshi Waza (Hip Techniques)	.1422*	.02339	.000	.0871	.1973
Movement Time	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	-.1095	.06818	.244	-.2701	.0510
		Ashi Waza (Leg Techniques)	.2286*	.06818	.003	.0680	.3891
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	.1095	.06818	.244	-.0510	.2701
		Ashi Waza (Leg Techniques)	.3381*	.06818	.000	.1775	.4987
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	-.2286*	.06818	.003	-.3891	-.0680
		Koshi Waza (Hip Techniques)	-.3381*	.06818	.000	-.4987	-.1775

Dependent Variable	(I) TACHI WAZA classification of Techniques	(J) TACHI WAZA classification of Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Height of CoG	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	.0112	.00514	.075	-.0009	.0233
		Ashi Waza (Leg Techniques)	-.0263*	.00514	.000	-.0384	-.0142
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	-.0112	.00514	.075	-.0233	.0009
		Ashi Waza (Leg Techniques)	-.0375*	.00514	.000	-.0496	-.0254
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	.0263*	.00514	.000	.0142	.0384
		Koshi Waza (Hip Techniques)	.0375*	.00514	.000	.0254	.0496
Angle of Hip Joint	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	7.6000	4.86294	.263	-3.8531	19.0531
		Ashi Waza (Leg Techniques)	-27.5048*	4.86294	.000	-38.9578	-16.0517
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	-7.6000	4.86294	.263	-19.0531	3.8531
		Ashi Waza (Leg Techniques)	-35.1048*	4.86294	.000	-46.5578	-23.6517
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	27.5048*	4.86294	.000	16.0517	38.9578
		Koshi Waza (Hip Techniques)	35.1048*	4.86294	.000	23.6517	46.5578
Angle of knee flexion	Te Waza (Hand Techniques)	Koshi Waza (Hip Techniques)	-33.4190*	2.87274	.000	-40.1849	-26.6532
		Ashi Waza (Leg Techniques)	-71.2381*	2.87274	.000	-78.0039	-64.4723
	Koshi Waza (Hip Techniques)	Te Waza (Hand Techniques)	33.4190*	2.87274	.000	26.6532	40.1849
		Ashi Waza (Leg Techniques)	-37.8190*	2.87274	.000	-44.5849	-31.0532
	Ashi Waza (Leg Techniques)	Te Waza (Hand Techniques)	71.2381*	2.87274	.000	64.4723	78.0039
		Koshi Waza (Hip Techniques)	37.8190*	2.87274	.000	31.0532	44.5849

\*. The mean difference is significant at the .05 level.

As the multivariate analysis revealed that there is significant difference among Tachi Waza classification of judo techniques, further analysis is needed to explain which classification of judo techniques makes the difference. Tukey's Post Hoc analysis is used to explain the difference. The result of the analysis is shown in the Table 15, which shows the Tukey's Post Hoc result for the kinematic variables among the Tachi Waza classification of judo techniques Hand Techniques.

For the Angular Velocity, it was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angular Displacement among the Nage Waza. It was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Movement Time, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.244), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

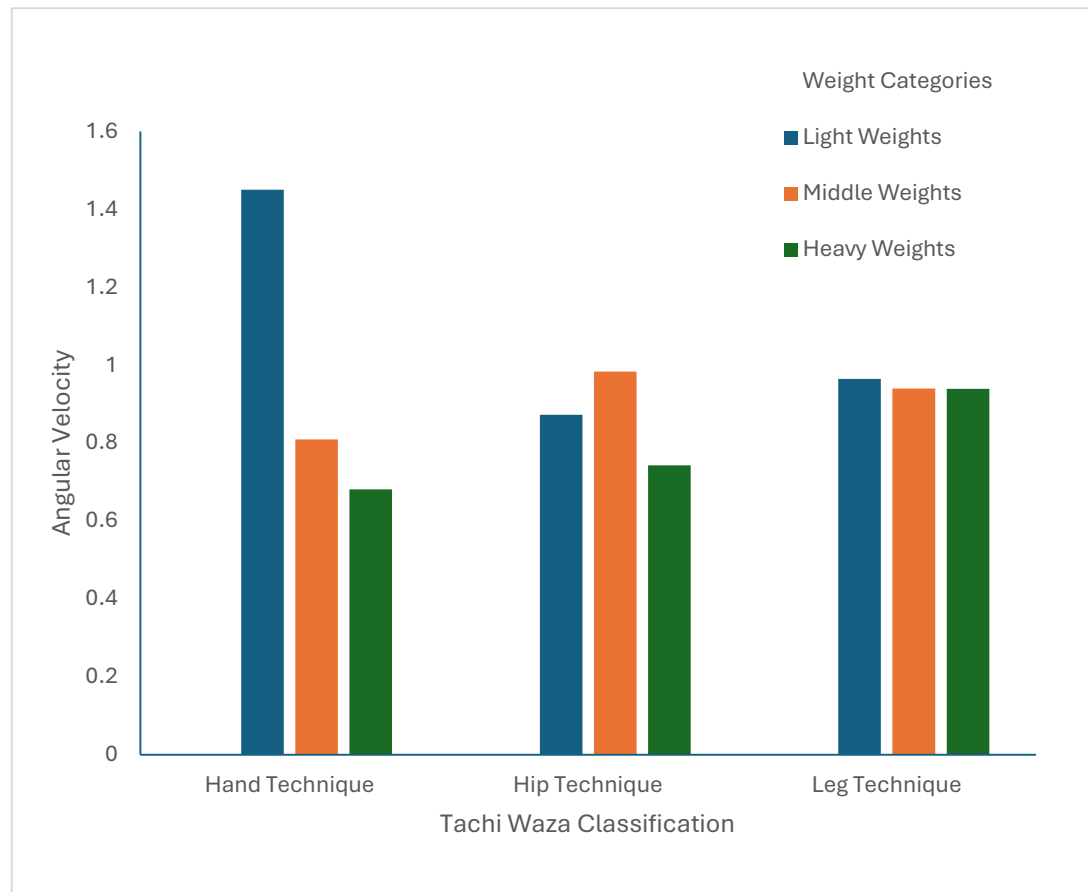
For the Height of CoG, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.075), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angle of Hip flexion, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.263), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

**Figure 34**

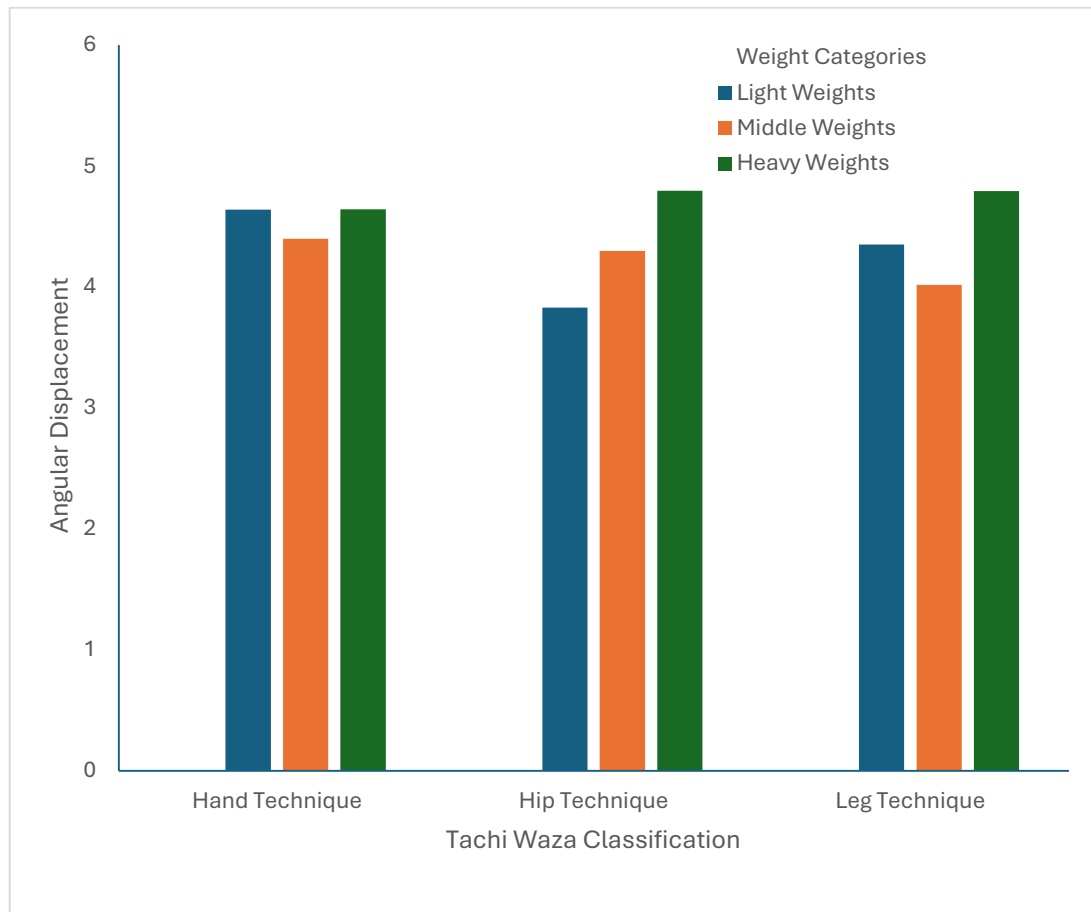
*Mean precedence of Angular Velocity corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Angular velocity corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 34 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The Angular Velocity seems predominant in Hand Techniques, were as light weight categories shows higher mean value as compared to the other weight categories.

**Figure 35**

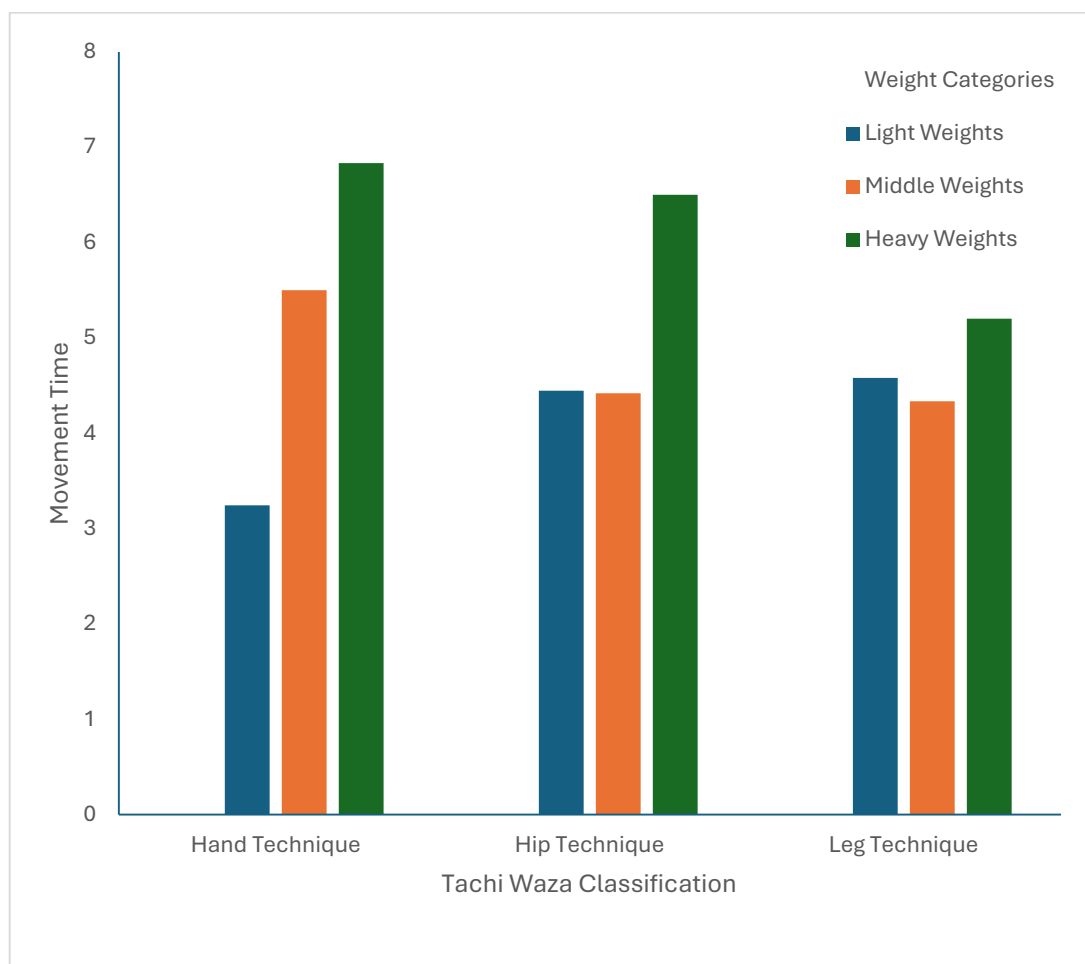
*Mean precedence of Angular Displacement corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Angular Displacement corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 35 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Angular Displacement shows higher in hip techniques as well as leg techniques among the heavy weight categories.

**Figure 36**

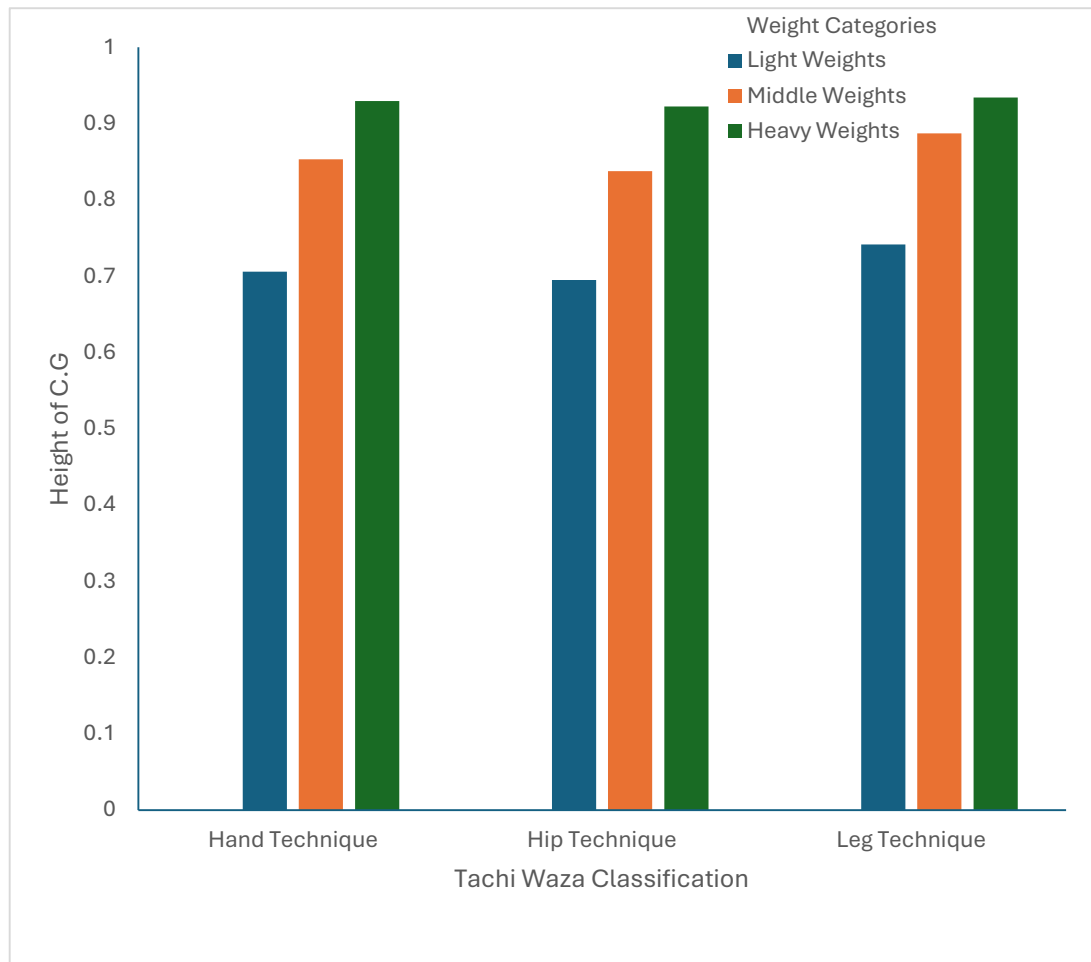
*Mean precedence of Movement Time corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Movement Time corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 36 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Movement Time was higher in Heavy Weight categories corresponding to the Tachi Waza classification where as the light weight categories the mean value seems lesser.

**Figure 37**

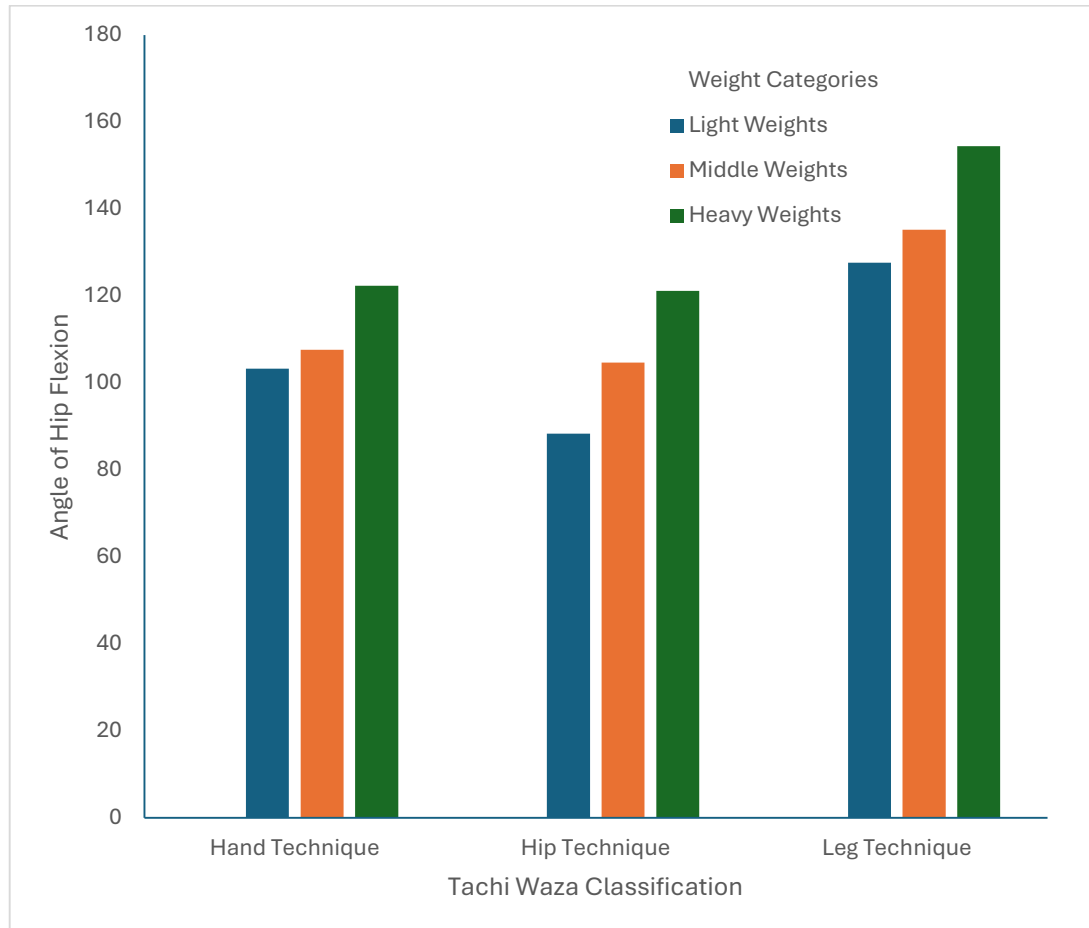
*Mean precedence of Height of Center of gravity corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Height of Center of gravity corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 37 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. Mean value of Height of Center of gravity was higher in heavy weight categories, were as mean value of Height of Center of gravity was lesser in light weight categories.

**Figure 38**

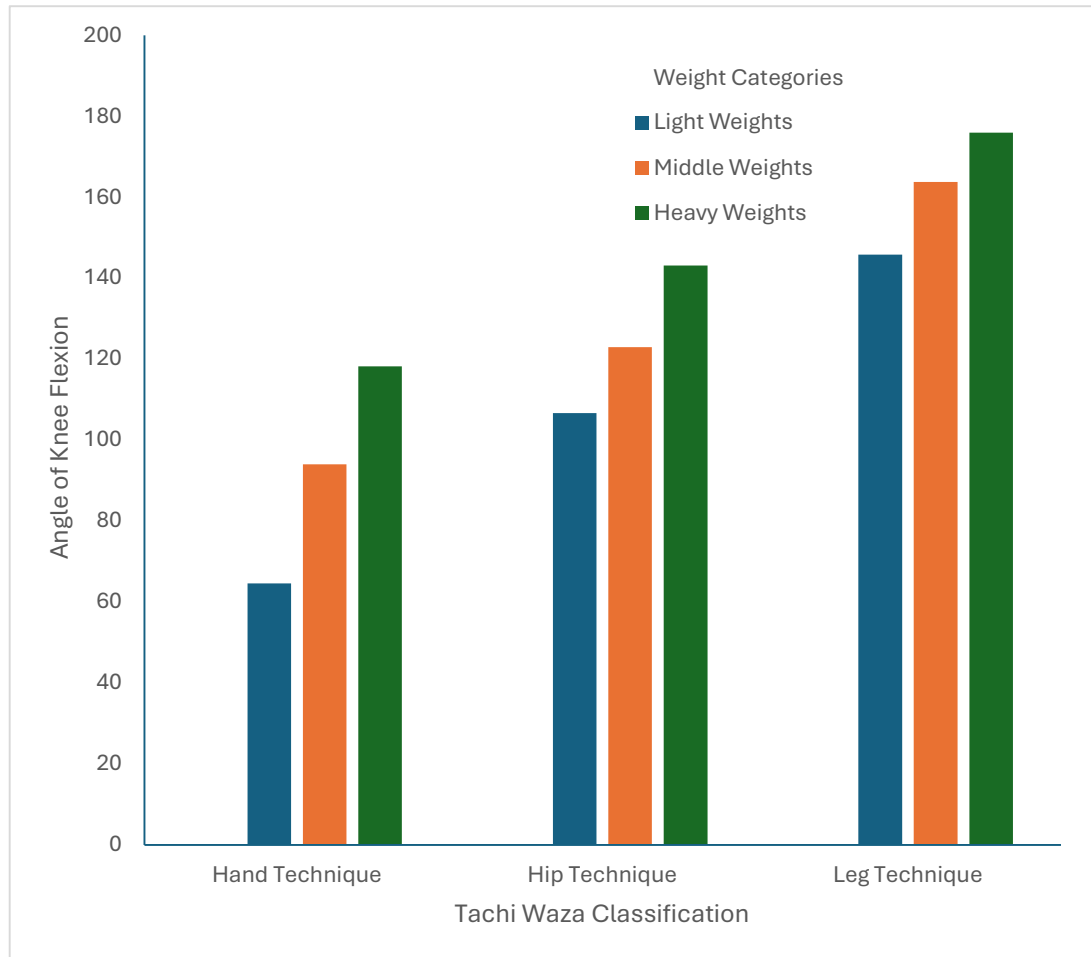
*Mean precedence of Angle Hip Joint corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Angle Hip Joint corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 38 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. Mean value of Angle of Hip Flexion was Obtuse Angles in Heavy weight categories as compared to the other weight categories. Whereas in light weight categories shows acute angle values corresponding to Hip techniques.

**Figure 39**

*Mean precedence of Angle of knee flexion corresponding to the Tachi Waza classification of Judo Techniques in accordance with weight categories*



The mean value of kinematic variable Angle of knee flexion corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 39 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Angle of knee flexion comes as Acute angles corresponding to hand techniques in accordance with light weight categories.

### **Analysis of kinematic variables in accordance with Competition weight categories among selected Judo Techniques**

Two-way ANOVA was done to each Kinematic Variables for which statistical hypothesis was framed as:

*H<sub>07</sub>: There is no significant difference in Angular Velocity in accordance competition weight categories among selected Judo Techniques.*

*H<sub>08</sub>: There is no significant difference in Angular Displacement in accordance competition weight categories among selected Judo Techniques*

*H<sub>09</sub>: There is no significant difference in Movement Time in accordance competition weight categories among selected Judo Techniques*

*H<sub>10</sub>: There is no significant difference in Height of CoG in accordance competition weight categories among selected Judo Techniques*

*H<sub>11</sub>: There is no significant difference in Angle of Hip Flexion in accordance competition weight categories among selected Judo Techniques*

*H<sub>12</sub>: There is no significant difference in Angle of knee flexion in accordance competition weight categories among selected Judo Techniques*

#### **1. Angular Velocity**

Angular velocity plays a significant role in the performance of judo techniques. Judo is a martial art that relies on using an opponent's force and balance against them. Angular velocity, which is the rate at which an object rotates around an axis, is crucial in executing throws and other techniques effectively. To find out whether there have any differences in Angular velocity in accordance with competition weight categories. The following statistical analysis were employed

### Analysis of Angular Velocity in accordance with Competition weight categories among selected judo techniques

Two-Way ANOVA was done for which hypothesis is framed as:

*H<sub>07</sub>: There is no significant difference in Angular Velocity in accordance competition categories among selected Judo Techniques.*

**Table 16**

*Descriptive of Angular Velocity in accordance with weight categories among selected Judo Techniques*

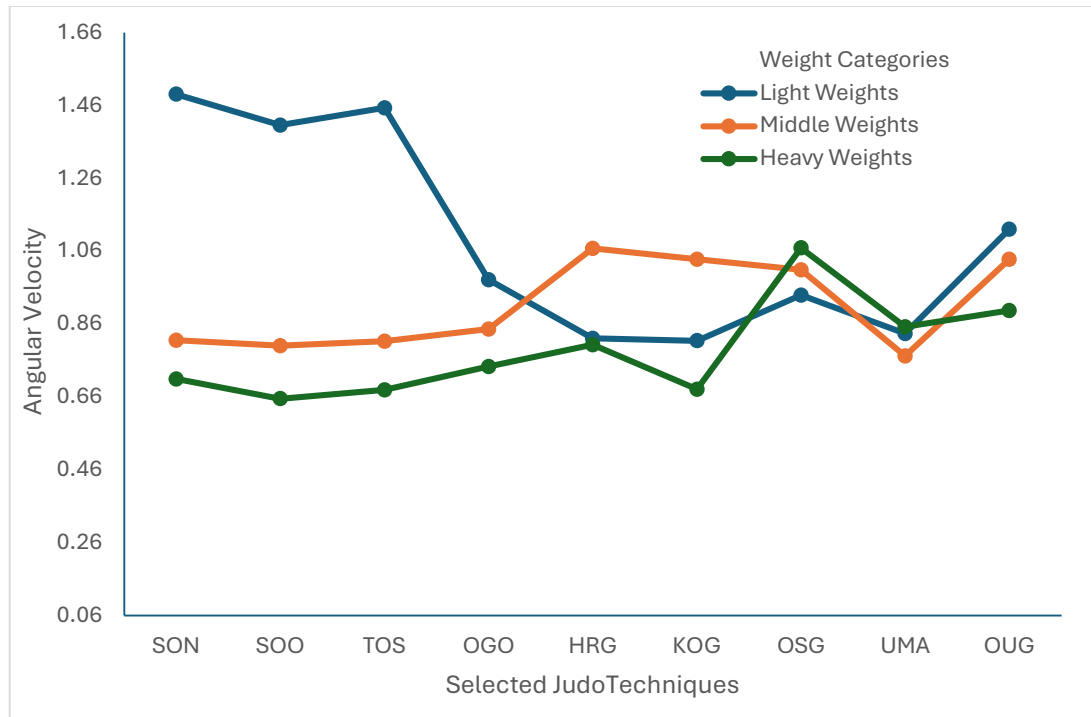
Weight Categories		Mean	Std. Deviation	N
Light Weights	SON	1.491	0.084	15
	SOO	1.406	0.192	15
	TOS	1.453	0.208	15
	OGO	0.981	0.012	15
	HRG	0.821	0.079	15
	KOG	0.814	0.089	15
	OSG	0.939	0.117	15
	UMA	0.834	0.012	15
	OUG	1.120	0.037	15
	Total	1.095	0.290	135
Middle Weights	SON	0.815	0.116	10
	SOO	0.800	0.108	10
	TOS	0.813	0.118	10
	OGO	0.846	0.020	10
	HRG	1.068	0.015	10
	KOG	1.038	0.091	10
	OSG	1.008	0.069	10
	UMA	0.772	0.053	10
	OUG	1.038	0.094	10
	Total	0.911	0.142	90

Weight Categories		Mean	Std. Deviation	N
Heavy Weights	SON	0.709	0.052	10
	SOO	0.655	0.007	10
	TOS	0.679	0.007	10
	OGO	0.743	0.068	10
	HRG	0.803	0.009	10
	KOG	0.681	0.007	10
	OSG	1.069	0.147	10
	UMA	0.852	0.078	10
	OUG	0.897	0.088	10
	Total	0.788	0.143	90
Total	SON	1.074	0.378	35
	SOO	1.018	0.371	35
	TOS	1.049	0.387	35
	OGO	0.874	0.108	35
	HRG	0.886	0.127	35
	KOG	0.840	0.157	35
	OSG	0.996	0.125	35
	UMA	0.821	0.059	35
	OUG	1.033	0.117	35
	Total	0.955	0.254	315

The means and standard deviation of angular velocity in the execution of selected techniques in accordance with the weight categories have been shown in Table 16 and it is found that the mean score is different in different weight categories

**Figure 40**

*Mean Comparison of Angular Velocity corresponding to the selected Judo Techniques*

**Table 17**

*ANOVA of the Kinematical Variable Angular Velocity in accordance with weight categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17.632 <sup>a</sup>	26	.678	75.125	.000
Intercept	263.421	1	263.421	29181.055	.000
Weight Categories	5.358	2	2.679	296.756	.000
Judo Techniques	1.632	8	.204	22.598	.000
Weight Categories * Judo Techniques	9.575	16	.598	66.296	.000
Error	2.600	288	.009		
Total	307.336	315			
Corrected Total	20.232	314			

a. R Squared = .872 (Adjusted R Squared = .860)

The results of the Two-way ANOVA were presented in the Table 17. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Velocity. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angular Velocity. The calculated F value of interaction between Weight Categories and Judo Techniques 66.296 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical null hypothesis  $H_0$  was failed to support.*

### Multiple Comparisons

**Table 18**

*Tukey's Post Hoc test for Angular Velocity in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	.0558	.02271	.257	-.0151	.1268
	TOS	.0253	.02271	.972	-.0457	.0963
	OGO	.1998*	.02271	.000	.1288	.2708
	HRG	.1882*	.02271	.000	.1172	.2591
	KOG	.2343*	.02271	.000	.1633	.3053
	OSG	.0783*	.02271	.019	.0073	.1493
	UMA	.2529*	.02271	.000	.1819	.3239
	OUG	.0416	.02271	.662	-.0294	.1125
SOO	SON	-.0558	.02271	.257	-.1268	.0151
	TOS	-.0305	.02271	.917	-.1015	.0405
	OGO	.1440*	.02271	.000	.0730	.2150
	HRG	.1323*	.02271	.000	.0613	.2033
	KOG	.1785*	.02271	.000	.1075	.2495
	OSG	.0224	.02271	.987	-.0486	.0934
	UMA	.1971*	.02271	.000	.1261	.2680
	OUG	-.0143	.02271	.999	-.0853	.0567

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TOS	SON	-.0253	.02271	.972	-.0963	.0457
	SOO	.0305	.02271	.917	-.0405	.1015
	OGO	.1745*	.02271	.000	.1035	.2455
	HRG	.1628*	.02271	.000	.0918	.2338
	KOG	.2090*	.02271	.000	.1380	.2800
	OSG	.0529	.02271	.327	-.0180	.1239
	UMA	.2276*	.02271	.000	.1566	.2986
	OUG	.0162	.02271	.999	-.0548	.0872
OGO	SON	-.1998*	.02271	.000	-.2708	-.1288
	SOO	-.1440*	.02271	.000	-.2150	-.0730
	TOS	-.1745*	.02271	.000	-.2455	-.1035
	HRG	-.0117	.02271	1.000	-.0826	.0593
	KOG	.0345	.02271	.846	-.0365	.1055
	OSG	-.1215*	.02271	.000	-.1925	-.0505
	UMA	.0531	.02271	.323	-.0179	.1241
	OUG	-.1583*	.02271	.000	-.2292	-.0873
HRG	SON	-.1882*	.02271	.000	-.2591	-.1172
	SOO	-.1323*	.02271	.000	-.2033	-.0613
	TOS	-.1628*	.02271	.000	-.2338	-.0918
	OGO	.0117	.02271	1.000	-.0593	.0826
	KOG	.0462	.02271	.522	-.0248	.1171
	OSG	-.1099*	.02271	.000	-.1809	-.0389
	UMA	.0647	.02271	.106	-.0062	.1357
	OUG	-.1466*	.02271	.000	-.2176	-.0756
KOG	SON	-.2343*	.02271	.000	-.3053	-.1633
	SOO	-.1785*	.02271	.000	-.2495	-.1075
	TOS	-.2090*	.02271	.000	-.2800	-.1380
	OGO	-.0345	.02271	.846	-.1055	.0365
	HRG	-.0462	.02271	.522	-.1171	.0248
	OSG	-.1560*	.02271	.000	-.2270	-.0851
	UMA	.0186	.02271	.996	-.0524	.0896
	OUG	-.1928*	.02271	.000	-.2638	-.1218
OSG	SON	-.0783*	.02271	.019	-.1493	-.0073
	SOO	-.0224	.02271	.987	-.0934	.0486
	TOS	-.0529	.02271	.327	-.1239	.0180
	OGO	.1215*	.02271	.000	.0505	.1925
	HRG	.1099*	.02271	.000	.0389	.1809
	KOG	.1560*	.02271	.000	.0851	.2270
	UMA	.1746*	.02271	.000	.1036	.2456
	OUG	-.0367	.02271	.795	-.1077	.0343

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UMA	SON	-.2529*	.02271	.000	-.3239	-.1819
	SOO	-.1971*	.02271	.000	-.2680	-.1261
	TOS	-.2276*	.02271	.000	-.2986	-.1566
	OGO	-.0531	.02271	.323	-.1241	.0179
	HRG	-.0647	.02271	.106	-.1357	.0062
	KOG	-.0186	.02271	.996	-.0896	.0524
	OSG	-.1746*	.02271	.000	-.2456	-.1036
	OUG	-.2114*	.02271	.000	-.2823	-.1404
OUG	SON	-.0416	.02271	.662	-.1125	.0294
	SOO	.0143	.02271	.999	-.0567	.0853
	TOS	-.0162	.02271	.999	-.0872	.0548
	OGO	.1583*	.02271	.000	.0873	.2292
	HRG	.1466*	.02271	.000	.0756	.2176
	KOG	.1928*	.02271	.000	.1218	.2638
	OSG	.0367	.02271	.795	-.0343	.1077
	UMA	.2114*	.02271	.000	.1404	.2823

Based on observed means.

The error term is Mean Square(Error) = .009.

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Angular Velocity on SON was observed that there was a significant difference between 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.019), 'SON', 'SON' and 'UMA' (.001), whereas there was no significant difference in between 'SON' and 'SOO' (.257), between 'SON' and 'TOS' (.972), 'SON' and 'OUG' (.662),

Post Hoc result for the Angular Velocity on SOO was observed that there was a significant difference between 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'UMA' (.001), whereas there was no significant difference in between 'SOO' and 'SON' (.257), between 'SOO' and 'TOS' (.917), 'SOO' and 'OSG' (.987), 'SOO' and 'OUG' (.999).

Post Hoc result for the Angular Velocity on TOS was observed that there was a significant difference between 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'UMA' (.001), whereas there was no significant difference in between 'TOS' and 'SOO' (.917), between 'TOS' and 'SON' (.972),

'TOS' and 'OUG' (.999), 'TOS' and 'OSG' (.327),

Post Hoc result for the Angular Velocity on OGO was observed that there was a significant difference between 'OGO' and 'SON' (.001), 'OGO' and 'SOO' (.001), 'OGO' and 'TOS' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001) Whereas there was no significant difference in between 'OGO and 'HRG' (1.000), 'OGO' and 'KOG' (.846), 'OGO and 'UMA' (.323).

Post Hoc result for the Angular Velocity on HRG was observed that there was significant difference in between 'HRG' and 'SON' (.001), 'HRG' and 'SOO' (.001), 'HRG' and 'TOS' (.001), 'HRG' and 'OSG' (.001) 'HRG 'and 'OUG' (.001), whereas there was no significant difference in between 'HRG' and 'OGO' (1.000), 'HRG' and 'KOG' (1.000), 'HRG' and 'UMA' (.106).

Post Hoc result for the Angular Velocity on KOG was observed that there was significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'SOO' (.001) 'KOG' and 'TOS' (.001) 'KOG' and 'OUG' (.001), 'KOG' and 'OSG' (.001), whereas there was no significant difference in between 'KOG' and 'OGO' (.8461), 'KOG' and 'HRG' (.522), 'KOG' and 'UMA' (.996).

Post Hoc result for the Angular Velocity on OSG was observed that there was a significant difference in between 'OSG' and 'SON' (.019), 'OSG' and 'OGO' (.001), 'OSG' and 'HRG' (.001), 'OSG' and 'KOG' (.001), 'OSG' and 'UMA' whereas there was no significant difference in between 'OSG' and 'SON' (.019), 'OSG' and 'SOO' (.987), 'OSG' and 'TOS' (.327), 'OSG' and 'OUG' (.795).

Post Hoc result for the Angular Velocity on UMA was observed that there was a significant difference in between 'UMA' and 'SON' (.001), 'UMA' and 'SOO' (.001), 'UMA' and 'TOS' (.001), 'UMA' and 'OSG' (.001), 'UMA' and 'OUG' (.001), whereas there was no significant difference in between 'UMA' and 'OGO' (.323), 'UMA' and 'HRG' (.106), 'UMA' and 'KOG' (.996).

Post Hoc result for the Angular Velocity on OUG was observed that there was a significant difference in between 'OUG' and 'OGO' (.001), 'OUG' and 'HRG'

(.001), 'OUG' and 'KOG' (.001), 'OUG' and 'UMA' (.001), whereas there was no significant difference 'OUG' and 'SON' (.662), 'OUG' and 'SOO' (.999), 'OUG' and 'TOS' (.999), 'OUG' and 'OSG' (.795).

## 2. Angular Displacement

Angular displacement, which refers to the change in the angular position of a rotating body, also plays a crucial role in the performance of judo techniques. In judo, precise control of angular displacement is essential for executing techniques with accuracy, balance, and effectiveness.

### Analysis of Angular Displacement in accordance with Competition weight categories among selected judo techniques

Two-Way ANOVA was done for which statistical hypothesis was framed as:

*H<sub>08</sub>: There is no significant difference in Angular displacement in accordance competition weight categories among selected Judo Techniques.*

**Table 19**

*Descriptive of Angular Displacement in accordance with weight categories among selected Judo Techniques*

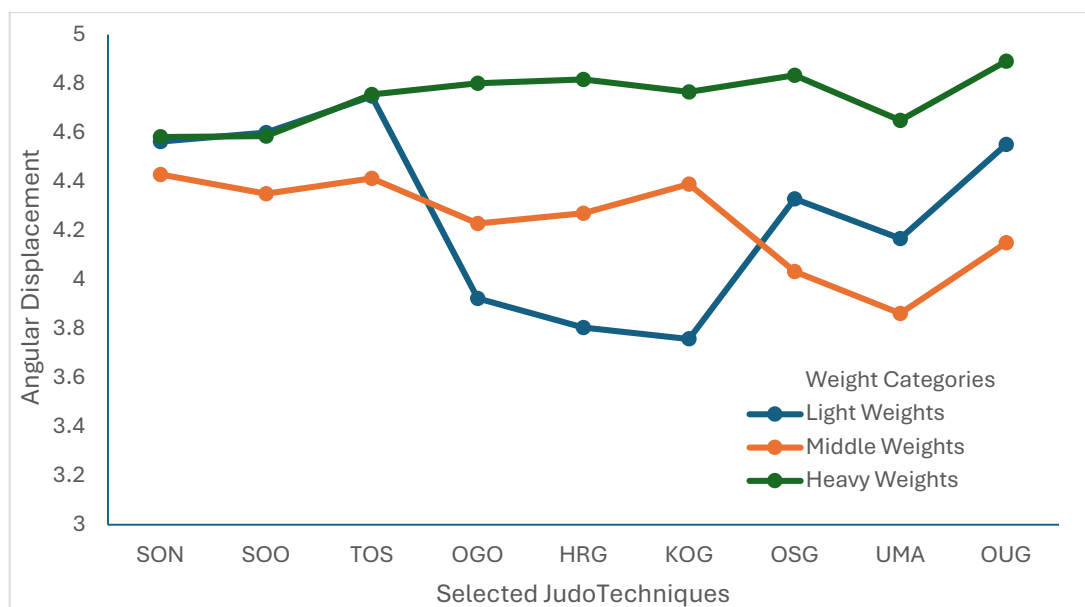
Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Light Weights	SON	4.5635	.12314	15
	SOO	4.5995	.04205	15
	TOS	4.7484	.06050	15
	OGO	3.9238	.04866	15
	HRG	3.8041	.31202	15
	KOG	3.7587	.03083	15
	OSG	4.3297	.07581	15
	UMA	4.1681	.06166	15
	OUG	4.5518	.06166	15
	Total	4.2720	.37270	135

Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Middle Weights	SON	4.4291	.21245	10
	SOO	4.3506	.17698	10
	TOS	4.4134	.22249	10
	OGO	4.2285	.10178	10
	HRG	4.2704	.05861	10
	KOG	4.3890	.11837	10
	OSG	4.0332	.27690	10
	UMA	3.8622	.26253	10
	OUG	4.1500	.37499	10
	Total	4.2363	.27861	90
Heavy Weights	SON	4.5827	.04728	10
	SOO	4.5861	.04684	10
	TOS	4.7554	.04666	10
	OGO	4.8007	.06870	10
	HRG	4.8164	.05544	10
	KOG	4.7658	.04564	10
	OSG	4.8339	.03627	10
	UMA	4.6489	.05532	10
	OUG	4.8914	.03875	10
	Total	4.7424	.11561	90
Total	SON	4.5306	.15193	35
	SOO	4.5246	.14863	35
	TOS	4.6547	.19788	35
	OGO	4.2614	.37564	35
	HRG	4.2265	.47272	35
	KOG	4.2265	.44104	35
	OSG	4.3890	.34642	35
	UMA	4.2181	.33701	35
	OUG	4.5341	.34679	35
	Total	4.3962	.36522	315

The means and standard deviation of Angular Displacement in the execution of selected techniques in accordance with the weight categories have been shown in Table 19 and it is found that the mean score is different in different weight categories

**Figure 41**

*Mean Comparison of Angular Displacement corresponding to the selected Judo Techniques*



**Table 20**

*ANOVA of the Kinematical Variable Angular Displacement in accordance with weight categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	35.837 <sup>a</sup>	26	1.378	65.659	.000
Intercept	5925.777	1	5925.777	282285.775	.000
Weight Categories	15.171	2	7.585	361.341	.000
Judo Techniques	5.287	8	.661	31.479	.000
Weight Categories * Judo Techniques	12.690	16	.793	37.783	.000
Error	6.046	288	.021		
Total	6129.659	315			
Corrected Total	41.882	314			

a. R Squared = .856 (Adjusted R Squared = .843)

The results of Two-way ANOVA were presented in the Table 20. It reveals that, the calculated F value of Weight Categories was 361.341 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Displacement. The calculated F value of selected Judo Techniques was 31.479, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angular Displacement. The calculated F value of interaction between Weight Categories and Judo Techniques 37.783 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical hypothesis  $H_{08}$  was failed to support.*

### Multiple Comparisons

**Table 21**

*Tukey's Post Hoc test for Angular Displacement in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	.0060	.03463	1.000	-.1023	.1142
	TOS	-.1241*	.03463	.012	-.2324	-.0159
	OGO	.2691*	.03463	.000	.1609	.3774
	HRG	.3040*	.03463	.000	.1958	.4123
	KOG	.3040*	.03463	.000	.1958	.4123
	OSG	.1415*	.03463	.002	.0333	.2498
	UMA	.3125*	.03463	.000	.2043	.4208
	OUG	-.0035	.03463	1.000	-.1117	.1048
SOO	SON	-.0060	.03463	1.000	-.1142	.1023
	TOS	-.1301*	.03463	.006	-.2383	-.0218
	OGO	.2632*	.03463	.000	.1549	.3714
	HRG	.2981*	.03463	.000	.1898	.4063
	KOG	.2981*	.03463	.000	.1898	.4063
	OSG	.1356*	.03463	.004	.0273	.2438
	UMA	.3065*	.03463	.000	.1983	.4148
	OUG	-.0095	.03463	1.000	-.1177	.0988

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TOS	SON	.1241*	.03463	.012	.0159	.2324
	SOO	.1301*	.03463	.006	.0218	.2383
	OGO	.3932*	.03463	.000	.2850	.5015
	HRG	.4281*	.03463	.000	.3199	.5364
	KOG	.4281*	.03463	.000	.3199	.5364
	OSG	.2657*	.03463	.000	.1574	.3739
	UMA	.4366*	.03463	.000	.3284	.5449
	OUG	.1206*	.03463	.017	.0124	.2289
OGO	SON	-.2691*	.03463	.000	-.3774	-.1609
	SOO	-.2632*	.03463	.000	-.3714	-.1549
	TOS	-.3932*	.03463	.000	-.5015	-.2850
	HRG	.0349	.03463	.985	-.0734	.1431
	KOG	.0349	.03463	.985	-.0734	.1431
	OSG	-.1276*	.03463	.008	-.2358	-.0193
	UMA	.0434	.03463	.944	-.0649	.1516
	OUG	-.2726*	.03463	.000	-.3809	-.1644
HRG	SON	-.3040*	.03463	.000	-.4123	-.1958
	SOO	-.2981*	.03463	.000	-.4063	-.1898
	TOS	-.4281*	.03463	.000	-.5364	-.3199
	OGO	-.0349	.03463	.985	-.1431	.0734
	KOG	.0000	.03463	1.000	-.1083	.1083
	OSG	-.1625*	.03463	.000	-.2707	-.0542
	UMA	.0085	.03463	1.000	-.0998	.1167
	OUG	-.3075*	.03463	.000	-.4158	-.1993
KOG	SON	-.3040*	.03463	.000	-.4123	-.1958
	SOO	-.2981*	.03463	.000	-.4063	-.1898
	TOS	-.4281*	.03463	.000	-.5364	-.3199
	OGO	-.0349	.03463	.985	-.1431	.0734
	HRG	.0000	.03463	1.000	-.1083	.1083
	OSG	-.1625*	.03463	.000	-.2707	-.0542
	UMA	.0085	.03463	1.000	-.0998	.1167
	OUG	-.3075*	.03463	.000	-.4158	-.1993

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
OSG	SON	-.1415*	.03463	.002	-.2498	-.0333
	SOO	-.1356*	.03463	.004	-.2438	-.0273
	TOS	-.2657*	.03463	.000	-.3739	-.1574
	OGO	.1276*	.03463	.008	.0193	.2358
	HRG	.1625*	.03463	.000	.0542	.2707
	KOG	.1625*	.03463	.000	.0542	.2707
	UMA	.1710*	.03463	.000	.0627	.2792
	OUG	-.1450*	.03463	.001	-.2533	-.0368
UMA	SON	-.3125*	.03463	.000	-.4208	-.2043
	SOO	-.3065*	.03463	.000	-.4148	-.1983
	TOS	-.4366*	.03463	.000	-.5449	-.3284
	OGO	-.0434	.03463	.944	-.1516	.0649
	HRG	-.0085	.03463	1.000	-.1167	.0998
	KOG	-.0085	.03463	1.000	-.1167	.0998
	OSG	-.1710*	.03463	.000	-.2792	-.0627
	OUG	-.3160*	.03463	.000	-.4242	-.2077
OUG	SON	.0035	.03463	1.000	-.1048	.1117
	SOO	.0095	.03463	1.000	-.0988	.1177
	TOS	-.1206*	.03463	.017	-.2289	-.0124
	OGO	.2726*	.03463	.000	.1644	.3809
	HRG	.3075*	.03463	.000	.1993	.4158
	KOG	.3075*	.03463	.000	.1993	.4158
	OSG	.1450*	.03463	.001	.0368	.2533
	UMA	.3160*	.03463	.000	.2077	.4242

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Angular Displacement on SON was observed that there was a significant difference in between 'SON' and 'TOS' (.012), 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.002), 'SON' and 'UMA' (.001), whereas there was no significant difference in between 'SON' and 'SOO' (1.000) and 'SON' and OUG' (1.000) respectively.

Post Hoc result for the Angular Displacement on SOO was observed that there was a significant difference in between 'SOO' and 'TOS' (.006), 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'OSG' (.004), 'SOO' and 'UMA' (.001), whereas there was no significant difference in between 'SOO' and 'SON' (1.000) and 'SOO' and OUG' (1.000) respectively.

Post Hoc result for the Angular Displacement on TOS was observed that there was a significant difference in between 'TOS' and 'SON' (.012), 'TOS' and 'SOO' (.006), 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'OSG' (.001), 'TOS' and 'UMA' (.001), 'TOS' and OUG' (.017) respectively.

Post Hoc result for the Angular Displacement on OGO was observed that there was a significant difference in between 'OGO' and 'SON' (.001), 'OGO' and 'SOO' (.001), 'OGO' and 'TOS' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001), whereas there was no significant in between 'OGO' and 'HRG' (.985) and 'OGO' and 'KOG' (.985), 'OUG' and 'UMA' (.944), respectively.

Post Hoc result for the Angular Displacement on HRG was observed that there was a significant difference in between 'HRG' and 'SON' (.001), 'HRG' and 'SOO' (.001), 'HRG' and 'TOS' (.001), 'HRG' and 'OSG' (.001), 'HRG' and 'OUG' (.001), whereas there was no significant difference in between 'HRG' and 'OGO' (.985) and 'HRG' and 'KOG' (1.000), 'HRG' and 'UMA' (1.000), respectively.

Post Hoc result for the Angular Displacement on KOG was observed that there was a significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'SOO' (.001), 'KOG' and 'TOS' (.001), 'KOG' and 'OSG' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'OGO' (.985) and

‘KOG’ and ‘HRG’ (1.000), ‘KOG’ and ‘UMA’ (1.000), respectively.

Post Hoc result for the Angular Displacement on OSG was observed that there was a significant difference in between ‘OSG’ and ‘SON’ (.002), ‘OSG’ and ‘SOO’ (.004), ‘OSG’ and ‘TOS’ (.001) ‘OSG’ and ‘OGO’ (.008), ‘OSG’ and ‘HRG’ (.001), ‘OSG’ and ‘KOG’ (.001), ‘OSG’ and ‘UMA’ (.001), ‘OSG’ and OUG’ (.001) respectively.

Post Hoc result for the Angular Displacement on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘SOO’ (.001), ‘UMA’ and ‘TOS’ (.001), ‘UMA’ and ‘OSG’ (.001), ‘UMA’ and ‘OUG’ (.001), whereas there was no significant difference in between ‘UMA’ and ‘OGO’ (.944) and ‘UMA’ and ‘HRG’ (1.000), ‘UMA’ and ‘KOG’ (1.000), respectively.

Post Hoc result for the Angular Displacement on OUG was observed that there was a significant difference in between, ‘OUG’ and ‘TOS’ (.017), ‘OUG’ and ‘OGO’ (.001) and ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001), ‘OUG’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OUG’ and ‘SON’ (1.000), ‘OUG’ and ‘SOO’ (1.000) respectively.

### **3. Movement Time**

Movement time, which is the duration taken to complete a movement or a sequence of movements, is a critical factor in the performance of judo techniques. Efficient and well-timed movements are essential for successful execution in judo.

Two-Way ANOVA was done for which statistical hypothesis was framed as:

*H<sub>09</sub>: There is no significant difference in Movement Time in accordance competition weight categories among selected Judo Techniques.*

**Table 22**

*Descriptive of Movement Time in accordance with weight categories among selected Judo Techniques*

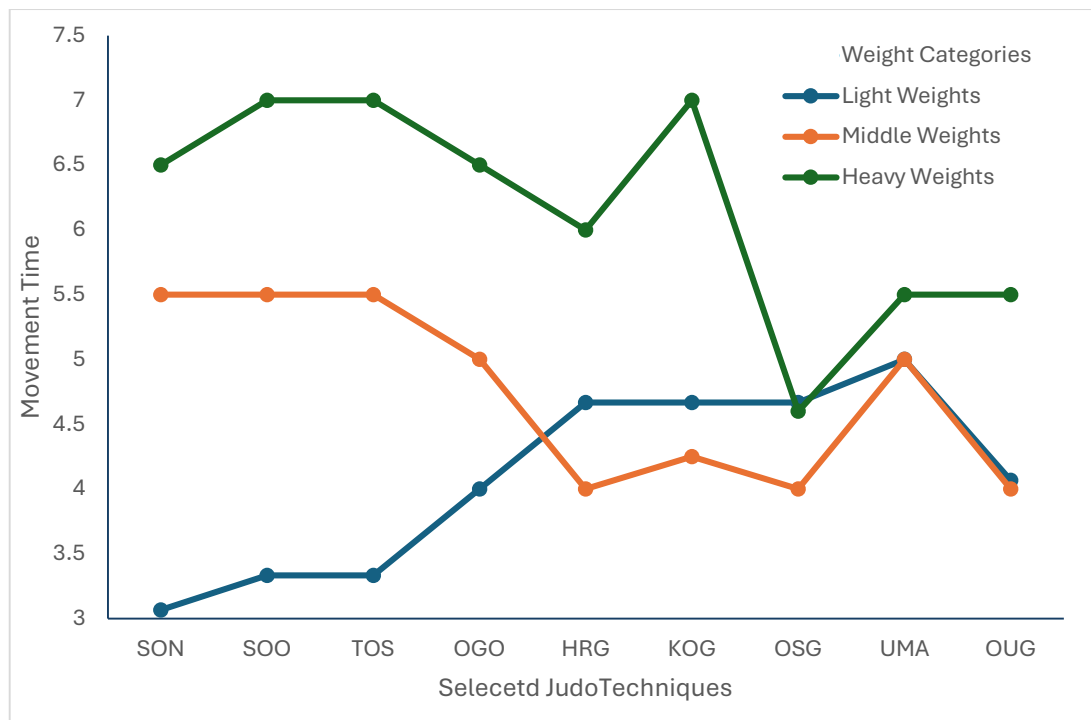
Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Light Weights	SON	3.0667	.09759	15
	SOO	3.3333	.48795	15
	TOS	3.3333	.48795	15
	OGO	4.0000	.00000	15
	HRG	4.6667	.48795	15
	KOG	4.6667	.48795	15
	OSG	4.6667	.48795	15
	UMA	5.0000	.00000	15
	OUG	4.0667	.09759	15
	Total	4.0889	.75968	135
Middle Weights	SON	5.5000	.52705	10
	SOO	5.5000	.52705	10
	TOS	5.5000	.52705	10
	OGO	5.0000	.00000	10
	HRG	4.0000	.00000	10
	KOG	4.2500	.26352	10
	OSG	4.0000	.00000	10
	UMA	5.0000	.00000	10
	OUG	4.0000	.00000	10
	Total	4.7500	.71599	90
Heavy Weights	SON	6.5000	.52705	10
	SOO	7.0000	.00000	10
	TOS	7.0000	.00000	10
	OGO	6.5000	.52705	10
	HRG	6.0000	.00000	10
	KOG	7.0000	.00000	10
	OSG	4.6000	.63246	10
	UMA	5.5000	.52705	10
	OUG	5.5000	.52705	10
	Total	6.1778	.88911	90

Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Total	SON	4.7429	1.57074	35
	SOO	5.0000	1.62698	35
	TOS	5.0000	1.62698	35
	OGO	5.0000	1.08465	35
	HRG	4.8571	.84515	35
	KOG	5.2143	1.20834	35
	OSG	4.4571	.53922	35
	UMA	5.1429	.35504	35
	OUG	4.4571	.72529	35
	Total		4.8746	1.17144

The means and standard deviation of Movement Time in the execution of selected techniques in accordance with the weight categories have been shown in Table 22 and it is found that the mean score is different in different weight categories

**Figure 42**

*Mean Comparison of Movement time corresponding to the selected Judo Techniques*



**Table 23**

*ANOVA of the Kinematical Variable Movement Time in accordance with weight categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	392.238 <sup>a</sup>	26	15.086	112.390	.000
Intercept	7610.634	1	7610.634	56698.324	.000
Weight Categories	237.583	2	118.791	884.982	.000
Judo Techniques	29.629	8	3.704	27.592	.000
Weight Categories * Judo Techniques	133.630	16	8.352	62.221	.000
Error	38.658	288	.134		
Total	7915.850	315			
Corrected Total	430.897	314			

a. R Squared = .910 (Adjusted R Squared = .902)

The results of the Two-way ANOVA were presented in the Table 23. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Movement Time. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Movement Time. The calculated F value of interaction between Weight Categories and Judo Techniques 62.221 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical hypothesis  $H_{09}$  failed to support.*

## Multiple Comparisons

**Table 24**

*Tukey's Post Hoc test for Movement Time in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	-.2571	.08758	.085	-.5309	.0166
	TOS	-.2571	.08758	.085	-.5309	.0166
	OGO	-.2571	.08758	.085	-.5309	.0166
	HRG	-.1143	.08758	.929	-.3880	.1595
	KOG	-.4714*	.08758	.000	-.7452	-.1977
	OSG	.2857*	.08758	.033	.0120	.5595
	UMA	-.4000*	.08758	.000	-.6737	-.1263
	OUG	.2857*	.08758	.033	.0120	.5595
SOO	SON	.2571	.08758	.085	-.0166	.5309
	TOS	.0000	.08758	1.000	-.2737	.2737
	OGO	.0000	.08758	1.000	-.2737	.2737
	HRG	.1429	.08758	.787	-.1309	.4166
	KOG	-.2143	.08758	.263	-.4880	.0595
	OSG	.5429*	.08758	.000	.2691	.8166
	UMA	-.1429	.08758	.787	-.4166	.1309
	OUG	.5429*	.08758	.000	.2691	.8166
TOS	SON	.2571	.08758	.085	-.0166	.5309
	SOO	.0000	.08758	1.000	-.2737	.2737
	OGO	.0000	.08758	1.000	-.2737	.2737
	HRG	.1429	.08758	.787	-.1309	.4166
	KOG	-.2143	.08758	.263	-.4880	.0595
	OSG	.5429*	.08758	.000	.2691	.8166
	UMA	-.1429	.08758	.787	-.4166	.1309
	OUG	.5429*	.08758	.000	.2691	.8166

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
OGO	SON	.2571	.08758	.085	-.0166	.5309
	SOO	.0000	.08758	1.000	-.2737	.2737
	TOS	.0000	.08758	1.000	-.2737	.2737
	HRG	.1429	.08758	.787	-.1309	.4166
	KOG	-.2143	.08758	.263	-.4880	.0595
	OSG	.5429*	.08758	.000	.2691	.8166
	UMA	-.1429	.08758	.787	-.4166	.1309
	OUG	.5429*	.08758	.000	.2691	.8166
HRG	SON	.1143	.08758	.929	-.1595	.3880
	SOO	-.1429	.08758	.787	-.4166	.1309
	TOS	-.1429	.08758	.787	-.4166	.1309
	OGO	-.1429	.08758	.787	-.4166	.1309
	KOG	-.3571*	.08758	.002	-.6309	-.0834
	OSG	.4000*	.08758	.000	.1263	.6737
	UMA	-.2857*	.08758	.033	-.5595	-.0120
	OUG	.4000*	.08758	.000	.1263	.6737
KOG	SON	.4714*	.08758	.000	.1977	.7452
	SOO	.2143	.08758	.263	-.0595	.4880
	TOS	.2143	.08758	.263	-.0595	.4880
	OGO	.2143	.08758	.263	-.0595	.4880
	HRG	.3571*	.08758	.002	.0834	.6309
	OSG	.7571*	.08758	.000	.4834	1.0309
	UMA	.0714	.08758	.996	-.2023	.3452
	OUG	.7571*	.08758	.000	.4834	1.0309
OSG	SON	-.2857*	.08758	.033	-.5595	-.0120
	SOO	-.5429*	.08758	.000	-.8166	-.2691
	TOS	-.5429*	.08758	.000	-.8166	-.2691
	OGO	-.5429*	.08758	.000	-.8166	-.2691
	HRG	-.4000*	.08758	.000	-.6737	-.1263
	KOG	-.7571*	.08758	.000	-1.0309	-.4834
	UMA	-.6857*	.08758	.000	-.9595	-.4120
	OUG	.0000	.08758	1.000	-.2737	.2737

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UMA	SON	.4000*	.08758	.000	.1263	.6737
	SOO	.1429	.08758	.787	-.1309	.4166
	TOS	.1429	.08758	.787	-.1309	.4166
	OGO	.1429	.08758	.787	-.1309	.4166
	HRG	.2857*	.08758	.033	.0120	.5595
	KOG	-.0714	.08758	.996	-.3452	.2023
	OSG	.6857*	.08758	.000	.4120	.9595
	OUG	.6857*	.08758	.000	.4120	.9595
OUG	SON	-.2857*	.08758	.033	-.5595	-.0120
	SOO	-.5429*	.08758	.000	-.8166	-.2691
	TOS	-.5429*	.08758	.000	-.8166	-.2691
	OGO	-.5429*	.08758	.000	-.8166	-.2691
	HRG	-.4000*	.08758	.000	-.6737	-.1263
	KOG	-.7571*	.08758	.000	-1.0309	-.4834
	OSG	.0000	.08758	1.000	-.2737	.2737
	UMA	-.6857*	.08758	.000	-.9595	-.4120

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Movement Time on SON was observed that there was a significant difference in between 'SON' and 'KOG' (.001) , 'SON' and 'OSG' (.033) 'SON' and 'UMA' (.001), 'SON' and OUG' (.033) whereas there was no significant difference in between 'SON' and 'SOO' (.085) , 'SON' and 'TOS' (.085), 'SON' and 'OGO' (.085), 'SON' and 'HRG' (.929) respectively.

Post Hoc result for the Movement Time on SOO was observed that there was a significant difference in between 'SOO' and 'OSG' (.001) , 'SOO' and OUG' (.001) whereas there was no significant difference in between 'SOO' and 'SON' (.085)' 'SOO' and 'TOS' (1.000), 'SOO' and 'OGO' (1.000), 'SOO' and 'HRG' (.787), 'SOO' and 'KOG' (.263) , 'SOO' and 'UMA' (.787) respectively.

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Post Hoc result for the Movement Time on TOS was observed that there was a significant difference in between 'TOS' and 'OSG' (.001), 'TOS' and 'OUG' (.001) whereas there was no significant difference in between 'TOS' and 'SON' (.085) 'TOS' and 'SOO' (1.000), 'TOS' and 'OGO' (1.000), 'TOS' and 'HRG' (.787), 'TOS' and 'KOG' (.263) , 'TOS' and 'UMA' (.787) respectively.

Post Hoc result for the Movement Time on OGO was observed that there was a significant difference in between 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001) whereas there was no significant difference in between 'OGO' and 'SON' (.085) 'OGO' and 'SOO' (1.000), 'OGO' and 'TOS' (1.000), 'OGO' and 'HRG' (.787), 'OGO' and 'KOG' (.263), 'OGO' and 'UMA' (.787) respectively.

Post Hoc result for the Movement Time on HRG was observed that there was a significant difference in between 'HRG' and 'KOG' (.002), 'HRG' and 'OSG' (.001) 'HRG' and 'UMA' (.033), 'HRG' and 'OUG' (.001) whereas there was no significant difference in between 'HRG' and 'SON' (.929)', 'HRG' and 'SOO' (.787)', 'HRG' and 'TOS' (.787), 'HRG' and 'OGO' (.787) respectively.

Post Hoc result for the Movement Time on KOG was observed that there was a significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'HRG' (.002), 'KOG' and 'OSG' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'SOO' (.263)', 'KOG' and 'TOS' (.263)', 'KOG' and 'OGO' (.985)', 'KOG' and 'UMA' (.996) respectively.

Post Hoc result for the Movement Time on OSG was observed that there was a significant difference in between OSG and 'SON' (.033), OSG and 'SOO' (.001), OSG and 'TOS' (.001), OSG and 'OGO' (.001), OSG and 'HRG' (.001), OSG and 'KOG' (.001), OSG and 'UMA' (.001), whereas there was no significant difference among in between 'OSG and 'OUG' (1.000) respectively.

Post Hoc result for the Movement Time on UMA was observed that there was a significant difference in between 'UMA' and 'SON' (.001), 'UMA' and 'HRG' (.033), 'UMA' and 'OSG' (.001), 'UMA' and 'OUG' (.001), whereas there was no significant difference in between 'UMA' and 'SOO' (.787)' and 'UMA' and 'TOS'

(.787), 'UMA' and 'OGO' (.787), 'UMA' and 'KOG' (.996) respectively.

Post Hoc result for the Movement Time on OUG was observed that there was a significant difference in between, 'OUG' and 'SON' (.033), 'OUG' and 'SOO' (.001) and 'OUG' and 'TOS' (.001), 'OUG' and 'OGO' (.001), 'OUG' and 'HRG' (.001), 'OUG' and 'KOG' (.001), 'OUG' and 'UMA' (.001), whereas there was no significant difference in between 'OUG' and 'OSG' (1.000) respectively.

#### 4. Height of Center of Gravity (CoG)

The height of the center of gravity is a critical factor in the performance of judo techniques. The center of gravity (CoG) is the point where the body's mass is concentrated, and its height can significantly affect a judoka's stability, balance, and ability to execute techniques

Two-Way ANOVA was done for which statistical hypothesis was framed as:

*H<sub>10</sub>: There is no significant difference in Height of Center of Gravity (CoG) in accordance competition weight categories among selected Judo Techniques.*

**Table 25**

*Descriptive of Height of Center of Gravity (CoG) in accordance with weight categories among selected Judo Techniques*

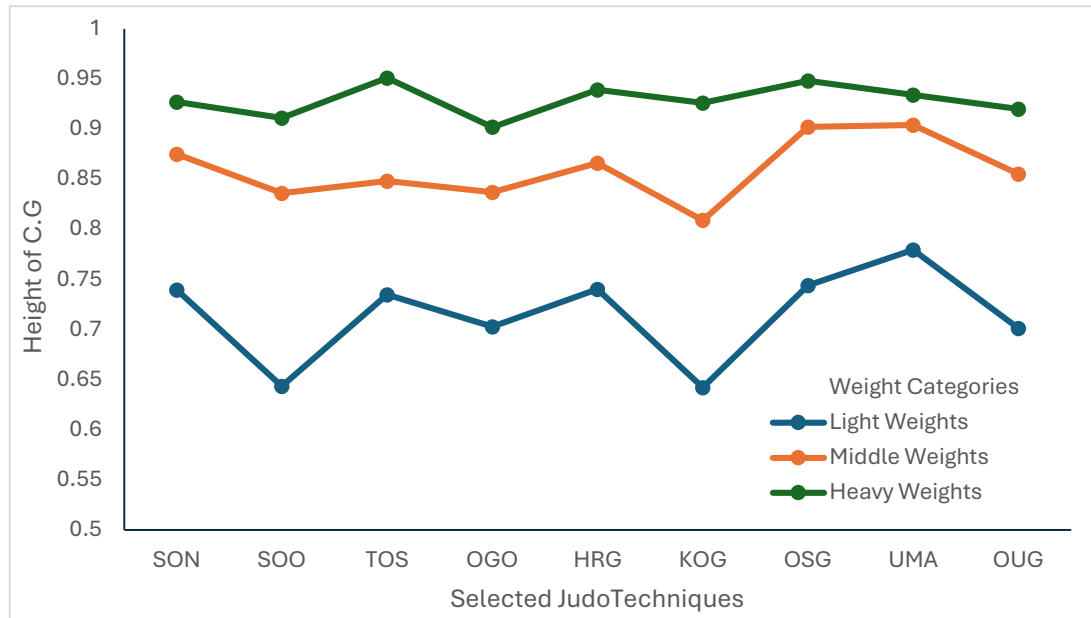
Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Light Weights	SON	.7393	.01486	15
	SOO	.6433	.00976	15
	TOS	.7347	.01125	15
	OGO	.7027	.01163	15
	HRG	.7400	.01558	15
	KOG	.6420	.01146	15
	OSG	.7440	.01183	15
	UMA	.7793	.00961	15
	OUG	.7011	.00922	15
	Total	.7141	.04559	135

Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Middle Weights	SON	.8750	.04089	10
	SOO	.8360	.01430	10
	TOS	.8480	.01135	10
	OGO	.8370	.02452	10
	HRG	.8660	.01430	10
	KOG	.8090	.09574	10
	OSG	.9020	.01619	10
	UMA	.9040	.02459	10
	OUG	.8550	.02224	10
	Total	.8591	.04721	90
Heavy Weights	SON	.9270	.01703	10
	SOO	.9110	.01853	10
	TOS	.9510	.01449	10
	OGO	.9020	.01398	10
	HRG	.9390	.01197	10
	KOG	.9260	.02503	10
	OSG	.9480	.00789	10
	UMA	.9340	.00966	10
	OUG	.9200	.01563	10
	Total	.9287	.02147	90
Total	SON	.8317	.08716	35
	SOO	.7749	.11986	35
	TOS	.8289	.09247	35
	OGO	.7980	.08891	35
	HRG	.8329	.08737	35
	KOG	.7709	.13221	35
	OSG	.8474	.09335	35
	UMA	.8591	.07261	35
	OUG	.8076	.09802	35
	Total	.8168	.10143	315

The means and standard deviation of Height of Center of Gravity (CoG) in the execution of selected techniques in accordance with the weight categories have been shown in Table 24 and it is found that the mean score is different in different weight categories

**Figure 43**

*Mean Comparison of Height of Center of gravity corresponding to the selected Judo Techniques*



**Table 26**

*ANOVA of the Kinematical Variable Height of Center of Gravity (CoG) in accordance with weight categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.073 <sup>a</sup>	26	.118	215.843	.000
Intercept	211.246	1	211.246	385797.980	.000
Weight Categories	2.713	2	1.356	2477.015	.000
Judo Techniques	.220	8	.027	50.139	.000
Weight Categories * Judo Techniques	.092	16	.006	10.499	.000
Error	.158	288	.001		
Total	213.395	315			
Corrected Total	3.231	314			

a. R Squared = .951 (Adjusted R Squared = .947)

The results of the Two-way ANOVA were presented in the Table 26. It reveals that, the calculated F value of Weight Categories was 2477.015, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to Height of Center of Gravity (CoG). The calculated F value of selected judo techniques was 50.139 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Height of Center of Gravity (CoG). The calculated F value of interaction between Weight Categories and Judo Techniques 10.499 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical null hypothesis  $H_{10}$  failed to support.*

### Multiple Comparisons

**Table 27**

*Tukey's Post Hoc test for Height of Center of Gravity (CoG) in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	.0569*	.00559	.000	.0394	.0743
	TOS	.0029	.00559	1.000	-.0146	.0203
	OGO	.0337*	.00559	.000	.0162	.0512
	HRG	-.0011	.00559	1.000	-.0186	.0163
	KOG	.0609*	.00559	.000	.0434	.0783
	OSG	-.0157	.00559	.117	-.0332	.0018
	UMA	-.0274*	.00559	.000	-.0449	-.0099
	OUG	.0241*	.00559	.001	.0066	.0416
SOO	SON	-.0569*	.00559	.000	-.0743	-.0394
	TOS	-.0540*	.00559	.000	-.0715	-.0365
	OGO	-.0231*	.00559	.002	-.0406	-.0057
	HRG	-.0580*	.00559	.000	-.0755	-.0405
	KOG	.0040	.00559	.999	-.0135	.0215
	OSG	-.0726*	.00559	.000	-.0901	-.0551
	UMA	-.0843*	.00559	.000	-.1018	-.0668
	OUG	-.0328*	.00559	.000	-.0503	-.0153

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TOS	SON	-.0029	.00559	1.000	-.0203	.0146
	SOO	.0540*	.00559	.000	.0365	.0715
	OGO	.0309*	.00559	.000	.0134	.0483
	HRG	-.0040	.00559	.999	-.0215	.0135
	KOG	.0580*	.00559	.000	.0405	.0755
	OSG	-.0186*	.00559	.028	-.0361	-.0011
	UMA	-.0303*	.00559	.000	-.0478	-.0128
	OUG	.0212*	.00559	.006	.0037	.0387
OGO	SON	-.0337*	.00559	.000	-.0512	-.0162
	SOO	.0231*	.00559	.002	.0057	.0406
	TOS	-.0309*	.00559	.000	-.0483	-.0134
	HRG	-.0349*	.00559	.000	-.0523	-.0174
	KOG	.0271*	.00559	.000	.0097	.0446
	OSG	-.0494*	.00559	.000	-.0669	-.0319
	UMA	-.0611*	.00559	.000	-.0786	-.0437
	OUG	-.0096	.00559	.733	-.0271	.0079
HRG	SON	.0011	.00559	1.000	-.0163	.0186
	SOO	.0580*	.00559	.000	.0405	.0755
	TOS	.0040	.00559	.999	-.0135	.0215
	OGO	.0349*	.00559	.000	.0174	.0523
	KOG	.0620*	.00559	.000	.0445	.0795
	OSG	-.0146	.00559	.189	-.0321	.0029
	UMA	-.0263*	.00559	.000	-.0438	-.0088
	OUG	.0252*	.00559	.000	.0077	.0427
KOG	SON	-.0609*	.00559	.000	-.0783	-.0434
	SOO	-.0040	.00559	.999	-.0215	.0135
	TOS	-.0580*	.00559	.000	-.0755	-.0405
	OGO	-.0271*	.00559	.000	-.0446	-.0097
	HRG	-.0620*	.00559	.000	-.0795	-.0445
	OSG	-.0766*	.00559	.000	-.0941	-.0591
	UMA	-.0883*	.00559	.000	-.1058	-.0708
	OUG	-.0368*	.00559	.000	-.0543	-.0193

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
OSG	SON	.0157	.00559	.117	-.0018	.0332
	SOO	.0726*	.00559	.000	.0551	.0901
	TOS	.0186*	.00559	.028	.0011	.0361
	OGO	.0494*	.00559	.000	.0319	.0669
	HRG	.0146	.00559	.189	-.0029	.0321
	KOG	.0766*	.00559	.000	.0591	.0941
	UMA	-.0117	.00559	.479	-.0292	.0058
	OUG	.0398*	.00559	.000	.0223	.0573
U MA	SON	.0274*	.00559	.000	.0099	.0449
	SOO	.0843*	.00559	.000	.0668	.1018
	TOS	.0303*	.00559	.000	.0128	.0478
	OGO	.0611*	.00559	.000	.0437	.0786
	HRG	.0263*	.00559	.000	.0088	.0438
	KOG	.0883*	.00559	.000	.0708	.1058
	OSG	.0117	.00559	.479	-.0058	.0292
	OUG	.0515*	.00559	.000	.0340	.0690
OUG	SON	-.0241*	.00559	.001	-.0416	-.0066
	SOO	.0328*	.00559	.000	.0153	.0503
	TOS	-.0212*	.00559	.006	-.0387	-.0037
	OGO	.0096	.00559	.733	-.0079	.0271
	HRG	-.0252*	.00559	.000	-.0427	-.0077
	KOG	.0368*	.00559	.000	.0193	.0543
	OSG	-.0398*	.00559	.000	-.0573	-.0223
	UMA	-.0515*	.00559	.000	-.0690	-.0340

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Height of Center of Gravity on SON was observed that there was a significant difference in between ‘SON’ and ‘SOO’ (.001), ‘SON’ and ‘OGO’ (.001), ‘SON’ and ‘KOG’ (.001), ‘SON’ and ‘UMA’ (.001), ‘SON’ and ‘OUG’ (.001) whereas there was no significant difference in between, ‘SON’ and ‘TOS’ (1.000), ‘SON’ and ‘HRG’ (1.000), ‘SON’ and ‘OSG’ (.117) respectively.

Post Hoc result for the Height of Center of Gravity on SOO was observed that there was a significant difference in between ‘SOO’ and ‘SON’ (.001) ‘SOO’ and

'TOS' (.001), 'SOO' and 'OGO' (.002), 'SOO' and 'HRG' (.001), "'SOO' and 'OSG' (.001), 'SOO' and 'UMA' (.001), 'SOO' and 'OUG' (.001) , whereas there was no significant difference in between 'SOO' and 'KOG' (.999) respectively.

Post Hoc result for the Height of Center of Gravity on TOS was observed that there was a significant difference in between 'TOS' and 'SOO' (.001), 'TOS' and 'OGO' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'OSG' (.028), 'TOS' and 'UMA' (.001), 'TOS' and 'OUG' (.006) whereas there was no significant difference in between 'TOS' and 'SON' (1.000) 'TOS' and 'HRG' (.999) respectively.

Post Hoc result for the Height of Center of Gravity on OGO was observed that there was a significant difference in between 'OGO' and 'SON' (.001)', 'OGO' and 'SOO' (.002), 'OGO' and 'TOS' (.001), 'OGO' and 'HRG' (.001), 'OGO' and 'KOG' (.001) , 'OGO' and 'OSG' (.001) 'OGO' and 'UMA' (.001), whereas there was no significant difference in between 'OGO' and 'OUG' (.733) respectively.

Post Hoc result for the Height of Center of Gravity on HRG was observed that there was a significant difference in between 'HRG' and 'SOO' (.001)' 'HRG' and 'OGO' (.001), 'HRG' and 'KOG' (.001), 'HRG' and 'UMA' (.001), 'HRG' and 'OUG' (.001) whereas there was no significant difference in between 'HRG' and 'SON' (1.000)', 'HRG' and 'TOS' (.999), 'HRG' and 'OSG' (.189) respectively.

Post Hoc result for the Height of Center of Gravity on KOG was observed that there was a significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'TOS' (.001)', 'KOG' and 'OGO' (.001), 'KOG' and 'HRG' (.001), 'KOG' and 'OSG' (.001), 'KOG' and 'UMA' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'SOO' (.999) respectively.

Post Hoc result for the Height of Center of Gravity on OSG was observed that there was a significant difference in between OSG and 'SOO' (.001), OSG and 'TOS' (.028), OSG and 'OGO' (.001), OSG and 'KOG' (.001), OSG and 'OUG' (.001), whereas there was no significant difference in between OSG and 'SON' (.117), 'OSG' and 'HRG' (.189), OSG and 'UMA' (.479) respectively.

Post Hoc result for the Height of Center of Gravity on UMA was observed that there was a significant difference in between 'UMA' and 'SON' (.001), 'UMA' and

‘SOO’ (.001) and ‘UMA’ and ‘TOS’ (.001), ‘UMA’ and ‘OGO’ (.001), ‘UMA’ and ‘KOG’ (.001), ‘UMA’ and ‘HRG’ (.001), ‘UMA’ and ‘OUG’ (.001) whereas there was no significant difference in between ‘UMA’ and ‘OSG’ (.479) respectively.

Post Hoc result for the Height of Center of Gravity on OUG was observed that there was a significant difference in between, ‘OUG’ and ‘SON’ (.001), ‘OUG’ and ‘SOO’ (.001) and ‘OUG’ and ‘TOS’ (.006), ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001) ‘OUG’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OUG’ and ‘OGO’ (.733), respectively.

### 5. Angle of Hip Flexion

The angle of the hip flexion is a crucial factor in the performance of judo techniques. Proper hip movement and positioning are essential for generating power, maintaining balance, and executing throws effectively.

Two-Way ANOVA was done for which statistical hypothesis was framed as:

*H<sub>11</sub>: There is no significant difference in Angle of Hip Flexion in accordance competition weight categories among selected Judo Techniques.*

**Table 28**

*Descriptive of Angle of Hip Flexion in accordance with weight categories among selected Judo Techniques*

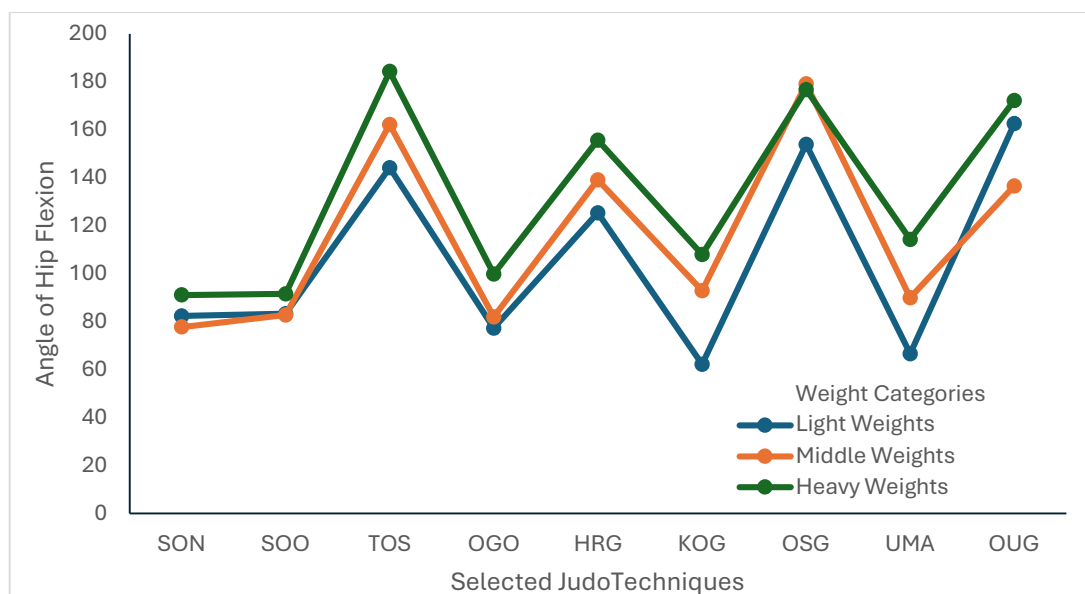
Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Light Weights	SON	82.3333	2.12692	15
	SOO	83.3333	2.02367	15
	TOS	144.2000	3.02844	15
	OGO	77.3333	2.28869	15
	HRG	125.4000	6.27694	15
	KOG	62.2000	3.42679	15
	OSG	153.8667	4.50185	15
	UMA	66.5333	4.12080	15
	OUG	162.5333	4.82355	15
	Total	106.4148	37.88048	135

Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Middle Weights	SON	77.8000	3.58391	10
	SOO	82.7000	2.83039	10
	TOS	162.2000	3.93841	10
	OGO	81.9000	5.58669	10
	HRG	139.1000	3.03498	10
	KOG	92.9000	3.47851	10
	OSG	179.2000	3.35989	10
	UMA	89.9000	2.96086	10
	OUG	136.5000	43.57178	10
	Total	115.8000	39.42656	90
Heavy Weights	SON	91.1000	1.28668	10
	SOO	91.6000	1.89737	10
	TOS	184.3000	7.87471	10
	OGO	99.8000	2.34758	10
	HRG	155.6000	7.16783	10
	KOG	108.0000	4.71405	10
	OSG	176.8000	2.34758	10
	UMA	114.3000	6.25478	10
	OUG	172.2000	2.89828	10
	Total	132.6333	37.20923	90
Total	SON	83.5429	5.73094	35
	SOO	85.5143	4.48115	35
	TOS	160.8000	17.57471	35
	OGO	85.0571	10.24966	35
	HRG	137.9429	13.91982	35
	KOG	84.0571	20.40320	35
	OSG	167.6571	12.66757	35
	UMA	86.8571	20.64282	35
	OUG	157.8571	26.80775	35
	Total	116.5873	39.54552	315

The means and standard deviation of Angle of Hip Flexion in the execution of selected techniques in accordance with the weight categories have been shown in Table 28 and it is found that the mean score is different in different weight categories

**Figure 44**

*Mean Comparison of Angle of Hip Flexion corresponding to the selected Judo Techniques*

**Table 29**

*ANOVA of the Kinematical Variable Angle of Hip Flexion in accordance with weight categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	469301.049 <sup>a</sup>	26	18050.040	239.037	.000
Intercept	4249705.778	1	4249705.778	56278.953	.000
Weight Categories	37198.279	2	18599.139	246.309	.000
Judo Techniques	394312.634	8	49289.079	652.736	.000
Weight Categories * Judo Techniques	22047.564	16	1377.973	18.249	.000
Error	21747.300	288	75.511		
Total	4772717.000	315			
Corrected Total	491048.349	314			

a. R Squared = .956 (Adjusted R Squared = .952)

The results of the Two-way ANOVA are presented in the Table 29. It reveals that, the calculated F value of Weight Categories was 246.309, which was significant

since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of Hip Joint. The calculated F value of selected judo techniques was 652.736, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angle of Hip Joint. The calculated F value of interaction between Weight Categories and Judo Techniques 18.249 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{11}$  failed to support.

### Multiple Comparisons

**Table 30**

*Tukey's Post Hoc test for Angle of Hip Flexion in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	-1.9714	2.07724	.990	-8.4640	4.5211
	TOS	-77.2571*	2.07724	.000	-83.7497	-70.7646
	OGO	-1.5143	2.07724	.998	-8.0068	4.9783
	HRG	-54.4000*	2.07724	.000	-60.8925	-47.9075
	KOG	-.5143	2.07724	1.000	-7.0068	5.9783
	OSG	-84.1143*	2.07724	.000	-90.6068	-77.6217
	UMA	-3.3143	2.07724	.807	-9.8068	3.1783
	OUG	-74.3143*	2.07724	.000	-80.8068	-67.8217
SOO	SON	1.9714	2.07724	.990	-4.5211	8.4640
	TOS	-75.2857*	2.07724	.000	-81.7783	-68.7932
	OGO	.4571	2.07724	1.000	-6.0354	6.9497
	HRG	-52.4286*	2.07724	.000	-58.9211	-45.9360
	KOG	1.4571	2.07724	.999	-5.0354	7.9497
	OSG	-82.1429*	2.07724	.000	-88.6354	-75.6503
	UMA	-1.3429	2.07724	.999	-7.8354	5.1497
	OUG	-72.3429*	2.07724	.000	-78.8354	-65.8503

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TOS	SON	77.2571*	2.07724	.000	70.7646	83.7497
	SOO	75.2857*	2.07724	.000	68.7932	81.7783
	OGO	75.7429*	2.07724	.000	69.2503	82.2354
	HRG	22.8571*	2.07724	.000	16.3646	29.3497
	KOG	76.7429*	2.07724	.000	70.2503	83.2354
	OSG	-6.8571*	2.07724	.030	-13.3497	-.3646
	UMA	73.9429*	2.07724	.000	67.4503	80.4354
	OUG	2.9429	2.07724	.891	-3.5497	9.4354
OGO	SON	1.5143	2.07724	.998	-4.9783	8.0068
	SOO	-.4571	2.07724	1.000	-6.9497	6.0354
	TOS	-75.7429*	2.07724	.000	-82.2354	-69.2503
	HRG	-52.8857*	2.07724	.000	-59.3783	-46.3932
	KOG	1.0000	2.07724	1.000	-5.4925	7.4925
	OSG	-82.6000*	2.07724	.000	-89.0925	-76.1075
	UMA	-1.8000	2.07724	.994	-8.2925	4.6925
	OUG	-72.8000*	2.07724	.000	-79.2925	-66.3075
HRG	SON	54.4000*	2.07724	.000	47.9075	60.8925
	SOO	52.4286*	2.07724	.000	45.9360	58.9211
	TOS	-22.8571*	2.07724	.000	-29.3497	-16.3646
	OGO	52.8857*	2.07724	.000	46.3932	59.3783
	KOG	53.8857*	2.07724	.000	47.3932	60.3783
	OSG	-29.7143*	2.07724	.000	-36.2068	-23.2217
	UMA	51.0857*	2.07724	.000	44.5932	57.5783
	OUG	-19.9143*	2.07724	.000	-26.4068	-13.4217
KOG	SON	.5143	2.07724	1.000	-5.9783	7.0068
	SOO	-1.4571	2.07724	.999	-7.9497	5.0354
	TOS	-76.7429*	2.07724	.000	-83.2354	-70.2503
	OGO	-1.0000	2.07724	1.000	-7.4925	5.4925
	HRG	-53.8857*	2.07724	.000	-60.3783	-47.3932
	OSG	-83.6000*	2.07724	.000	-90.0925	-77.1075
	UMA	-2.8000	2.07724	.916	-9.2925	3.6925
	OUG	-73.8000*	2.07724	.000	-80.2925	-67.3075

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
OSG	SON	84.1143*	2.07724	.000	77.6217	90.6068
	SOO	82.1429*	2.07724	.000	75.6503	88.6354
	TOS	6.8571*	2.07724	.030	.3646	13.3497
	OGO	82.6000*	2.07724	.000	76.1075	89.0925
	HRG	29.7143*	2.07724	.000	23.2217	36.2068
	KOG	83.6000*	2.07724	.000	77.1075	90.0925
	UMA	80.8000*	2.07724	.000	74.3075	87.2925
	OUG	9.8000*	2.07724	.000	3.3075	16.2925
UMA	SON	3.3143	2.07724	.807	-3.1783	9.8068
	SOO	1.3429	2.07724	.999	-5.1497	7.8354
	TOS	-73.9429*	2.07724	.000	-80.4354	-67.4503
	OGO	1.8000	2.07724	.994	-4.6925	8.2925
	HRG	-51.0857*	2.07724	.000	-57.5783	-44.5932
	KOG	2.8000	2.07724	.916	-3.6925	9.2925
	OSG	-80.8000*	2.07724	.000	-87.2925	-74.3075
	OUG	-71.0000*	2.07724	.000	-77.4925	-64.5075
OUG	SON	74.3143*	2.07724	.000	67.8217	80.8068
	SOO	72.3429*	2.07724	.000	65.8503	78.8354
	TOS	-2.9429	2.07724	.891	-9.4354	3.5497
	OGO	72.8000*	2.07724	.000	66.3075	79.2925
	HRG	19.9143*	2.07724	.000	13.4217	26.4068
	KOG	73.8000*	2.07724	.000	67.3075	80.2925
	OSG	-9.8000*	2.07724	.000	-16.2925	-3.3075
	UMA	71.0000*	2.07724	.000	64.5075	77.4925

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Angle of Hip Flexion on SON was observed that there was a significant difference in between 'SON' and 'TOS' (.001)', 'SON' and 'HRG' (.001), 'SON' and 'OSG' (.001) , 'SON' and 'OUG' (.001), whereas there was no significant difference in between, 'SON' and 'SOO' (.990), 'SON' and 'OGO' (.998), 'SON' and 'KOG' (1.000) 'SON' and 'UMA' (.807), respectively.

Post Hoc result for the Angle of Hip Flexion on SOO was observed that there was a significant difference in between 'SOO' and 'TOS' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'OSG' (.001) , 'SOO' and OUG' (.001), whereas there was no significant difference in between 'SOO' and 'SON' (.990)' 'SOO' and 'OGO' (1.00), 'SOO' and 'KOG' (.999), 'SOO' and 'UMA' (.999) respectively.

Post Hoc result for the Angle of Hip Flexion on TOS was observed that there was a significant difference in between 'TOS' and 'SON' (.001)' 'TOS' and 'SOO' (.001), 'TOS' and 'OGO' (.001), TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001) , 'TOS' and 'OSG' (.030), 'TOS' and 'UMA' (.001), whereas there was no significant difference in between 'TOS' and 'OUG' (.0891) respectively.

Post Hoc result for the Angle of Hip Flexion on OGO was observed that there was a significant difference in between 'OGO' and 'TOS' (.001), 'OGO' and 'HRG' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001) whereas there was no significant difference in between 'OGO' and 'SON' (.998)', 'OGO' and 'SOO' (1.000), 'OGO' and 'KOG' (1.000) 'OGO' and 'UMA' (.994), respectively.

Post Hoc result for the Angle of Hip Flexion on HRG was observed that there was a significant difference in between 'HRG' and 'SON' (.001)', 'HRG' and 'SOO' (.001)' 'HRG' and 'TOS' (.001)' 'HRG' and 'OGO' (.001), 'HRG' and 'KOG' (.001), 'HRG' and 'OSG' (.189) 'HRG' and 'UMA' (.001), 'HRG' and OUG' (.001) respectively.

Post Hoc result for the Angle of Hip Flexion on KOG was observed that there was a significant difference in between 'KOG' and 'TOS' (.001), 'KOG' and 'HRG' (.001)', 'KOG' and 'OSG' (.001), 'KOG' and 'HRG' (.001), 'KOG' and 'OUG' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'SON' (1.000), 'KOG' and 'SOO' (.999)' 'KOG' and 'OGO' (1.000) 'KOG' and 'UMA' (.916) respectively.

Post Hoc result for the Angle of Hip Flexion on OSG was observed that there was a significant difference in between 'OSG' and 'SON' (.001), 'OSG' and 'SOO' (.001), 'OSG' and 'TOS' (.030), 'OSG' and 'OGO' (.001), 'OSG' and 'HRG' (.001), 'OSG' and 'KOG' (.001), 'OSG' and 'UMA' (.001), 'OSG' and 'OUG' (.001) respectively.

Post Hoc result for the Angle of Hip Flexion on UMA was observed that there was a significant difference in between 'UMA' and 'TOS' (.001), 'UMA' and 'HRG' (.001) 'UMA' and 'OSG' (.001), 'UMA' and 'OUG' (.001) whereas there was no significant difference in between 'UMA' and 'SON' (.807), 'UMA' and 'SOO' (.999) 'UMA' and 'OGO' (.994), 'UMA' and 'KOG' (.916) 'UMA' and 'OSG' (.479) respectively.

Post Hoc result for the Angle of Hip Flexion on OUG was observed that there was a significant difference in between, 'OUG' and 'SON' (.001), 'OUG' and 'SOO' (.001), 'OUG' and 'OGO' (.001), 'OUG' and 'HRG' (.001), 'OUG' and 'KOG' (.001), 'OUG' and 'OSG' (.001) 'OUG' and 'UMA' (.001), whereas there was no significant difference in between 'OUG' and 'TOS' (.891), respectively.

## **6. Angle of knee flexion**

The angle of the knee flexion is a significant factor in the performance of judo techniques. The knee joint plays a crucial role in maintaining balance, generating power, and executing various movements in judo.

Two-Way ANOVA was done for which statistical hypothesis was framed as:

*H<sub>12</sub>: There is no significant difference in Angle of knee flexion in accordance competition categories among selected Judo Techniques.*

**Table 31**

*Descriptive of Angle of knee flexion in accordance with weight categories among selected Judo Techniques*

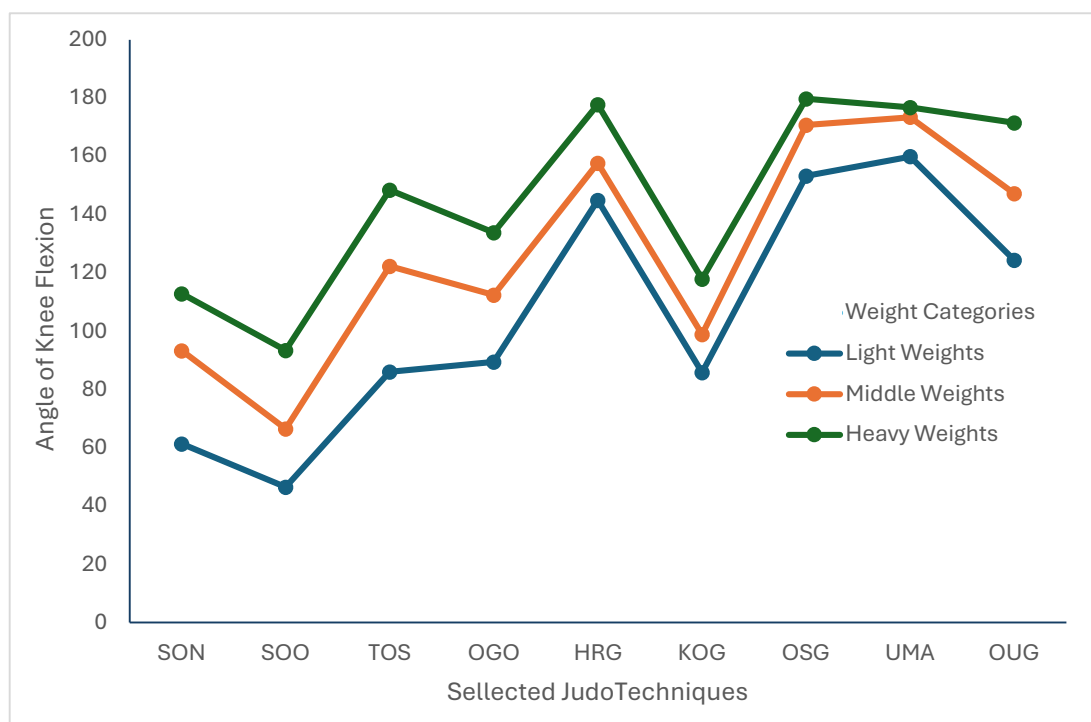
Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Light Weights	SON	61.2667	1.94447	15
	SOO	46.4667	3.68136	15
	TOS	86.0000	3.56571	15
	OGO	89.4000	2.29285	15
	HRG	144.8667	3.60291	15
	KOG	85.7333	3.51460	15
	OSG	153.2000	2.62406	15
	UMA	159.8667	2.06559	15
	OUG	124.3333	5.34077	15
	Total	105.6815	39.16167	135
Middle Weights	SON	93.3000	1.63639	10
	SOO	66.5000	3.89444	10
	TOS	122.2000	2.89828	10
	OGO	112.4000	2.27058	10
	HRG	157.6000	2.41293	10
	KOG	98.8000	1.75119	10
	OSG	170.7000	3.19896	10
	UMA	173.4000	3.62706	10
	OUG	147.2000	3.45768	10
	Total	126.9000	35.63613	90
Heavy Weights	SON	112.8000	2.20101	10
	SOO	93.4000	6.41526	10
	TOS	148.4000	3.09839	10
	OGO	133.8000	3.55278	10
	HRG	177.7000	3.12872	10
	KOG	117.8000	4.44222	10
	OSG	179.7000	1.49443	10
	UMA	176.7000	3.19896	10
	OUG	171.4000	3.65756	10
	Total	145.7444	31.18937	90

Weight Categories	Judo Techniques	Mean	Std. Deviation	N
Total	SON	85.1429	22.35166	35
	SOO	65.6000	20.23712	35
	TOS	114.1714	26.90122	35
	OGO	108.6571	18.98752	35
	HRG	157.8857	14.13334	35
	KOG	98.6286	13.87780	35
	OSG	165.7714	11.83486	35
	UMA	168.5429	8.22601	35
	OUG	144.3143	20.31773	35
	Total		123.1905	39.64470

The means and standard deviation of Angle of knee flexion in the execution of selected techniques in accordance with the weight categories have been shown in Table 31 and it is found that the mean score is different in different weight categories.

**Table 45**

*Mean Comparison of Angle of knee flexion corresponding to the selected Judo Techniques*



**Table 32**

*ANOVA of the Kinematical Variable Angle of knee flexion in accordance with weight Categories corresponding to selected Judo Techniques*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	490317.171 <sup>a</sup>	26	18858.353	1698.632	.000
Intercept	4830654.585	1	4830654.585	435112.442	.000
Weight Categories	88406.046	2	44203.023	3981.507	.000
Judo Techniques	365710.765	8	45713.846	4117.592	.000
Weight Categories * Judo Techniques	10608.212	16	663.013	59.720	.000
Error	3197.400	288	11.102		
Total	5273921.000	315			
Corrected Total	493514.571	314			

a. R Squared = .994 (Adjusted R Squared = .993)

The results of the Two-way ANOVA were presented in the Table 32. It reveals that, the calculated F value of Weight Categories was 3981.507, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of knee flexion. The calculated F value of selected judo techniques was 4117.592, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angle of knee flexion. The calculated F value of interaction between Weight Categories and Judo Techniques 59.720 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. *Therefore, the statistical hypothesis  $H_{12}$  failed to support.*

## Multiple Comparisons

**Table 33**

*Tukey's Post Hoc test for Angle of Knee Flexion in accordance with weight categories corresponding to Selected judo techniques*

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SON	SOO	19.5429*	.79650	.000	17.0534	22.0323
	TOS	-29.0286*	.79650	.000	-31.5181	-26.5391
	OGO	-23.5143*	.79650	.000	-26.0038	-21.0248
	HRG	-72.7429*	.79650	.000	-75.2323	-70.2534
	KOG	-13.4857*	.79650	.000	-15.9752	-10.9962
	OSG	-80.6286*	.79650	.000	-83.1181	-78.1391
	UMA	-83.4000*	.79650	.000	-85.8895	-80.9105
	OUG	-59.1714*	.79650	.000	-61.6609	-56.6819
SOO	SON	-19.5429*	.79650	.000	-22.0323	-17.0534
	TOS	-48.5714*	.79650	.000	-51.0609	-46.0819
	OGO	-43.0571*	.79650	.000	-45.5466	-40.5677
	HRG	-92.2857*	.79650	.000	-94.7752	-89.7962
	KOG	-33.0286*	.79650	.000	-35.5181	-30.5391
	OSG	-100.1714*	.79650	.000	-102.6609	-97.6819
	UMA	-102.9429*	.79650	.000	-105.4323	-100.4534
	OUG	-78.7143*	.79650	.000	-81.2038	-76.2248
TOS	SON	29.0286*	.79650	.000	26.5391	31.5181
	SOO	48.5714*	.79650	.000	46.0819	51.0609
	OGO	5.5143*	.79650	.000	3.0248	8.0038
	HRG	-43.7143*	.79650	.000	-46.2038	-41.2248
	KOG	15.5429*	.79650	.000	13.0534	18.0323
	OSG	-51.6000*	.79650	.000	-54.0895	-49.1105
	UMA	-54.3714*	.79650	.000	-56.8609	-51.8819
	OUG	-30.1429*	.79650	.000	-32.6323	-27.6534

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
OGO	SON	23.5143*	.79650	.000	21.0248	26.0038
	SOO	43.0571*	.79650	.000	40.5677	45.5466
	TOS	-5.5143*	.79650	.000	-8.0038	-3.0248
	HRG	-49.2286*	.79650	.000	-51.7181	-46.7391
	KOG	10.0286*	.79650	.000	7.5391	12.5181
	OSG	-57.1143*	.79650	.000	-59.6038	-54.6248
	UMA	-59.8857*	.79650	.000	-62.3752	-57.3962
	OUG	-35.6571*	.79650	.000	-38.1466	-33.1677
HRG	SON	72.7429*	.79650	.000	70.2534	75.2323
	SOO	92.2857*	.79650	.000	89.7962	94.7752
	TOS	43.7143*	.79650	.000	41.2248	46.2038
	OGO	49.2286*	.79650	.000	46.7391	51.7181
	KOG	59.2571*	.79650	.000	56.7677	61.7466
	OSG	-7.8857*	.79650	.000	-10.3752	-5.3962
	UMA	-10.6571*	.79650	.000	-13.1466	-8.1677
	OUG	13.5714*	.79650	.000	11.0819	16.0609
KOG	SON	13.4857*	.79650	.000	10.9962	15.9752
	SOO	33.0286*	.79650	.000	30.5391	35.5181
	TOS	-15.5429*	.79650	.000	-18.0323	-13.0534
	OGO	-10.0286*	.79650	.000	-12.5181	-7.5391
	HRG	-59.2571*	.79650	.000	-61.7466	-56.7677
	OSG	-67.1429*	.79650	.000	-69.6323	-64.6534
	UMA	-69.9143*	.79650	.000	-72.4038	-67.4248
	OUG	-45.6857*	.79650	.000	-48.1752	-43.1962
OSG	SON	80.6286*	.79650	.000	78.1391	83.1181
	SOO	100.1714*	.79650	.000	97.6819	102.6609
	TOS	51.6000*	.79650	.000	49.1105	54.0895
	OGO	57.1143*	.79650	.000	54.6248	59.6038
	HRG	7.8857*	.79650	.000	5.3962	10.3752
	KOG	67.1429*	.79650	.000	64.6534	69.6323
	UMA	-2.7714*	.79650	.017	-5.2609	-.2819
	OUG	21.4571*	.79650	.000	18.9677	23.9466

(I) Judo Techniques	(J) Judo Techniques	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UMA	SON	83.4000*	.79650	.000	80.9105	85.8895
	SOO	102.9429*	.79650	.000	100.4534	105.4323
	TOS	54.3714*	.79650	.000	51.8819	56.8609
	OGO	59.8857*	.79650	.000	57.3962	62.3752
	HRG	10.6571*	.79650	.000	8.1677	13.1466
	KOG	69.9143*	.79650	.000	67.4248	72.4038
	OSG	2.7714*	.79650	.017	.2819	5.2609
	OUG	24.2286*	.79650	.000	21.7391	26.7181
OUG	SON	59.1714*	.79650	.000	56.6819	61.6609
	SOO	78.7143*	.79650	.000	76.2248	81.2038
	TOS	30.1429*	.79650	.000	27.6534	32.6323
	OGO	35.6571*	.79650	.000	33.1677	38.1466
	HRG	-13.5714*	.79650	.000	-16.0609	-11.0819
	KOG	45.6857*	.79650	.000	43.1962	48.1752
	OSG	-21.4571*	.79650	.000	-23.9466	-18.9677
	UMA	-24.2286*	.79650	.000	-26.7181	-21.7391

\*. The mean difference is significant at the .05 level.

Post Hoc result for the Angle of knee flexion on SON was observed that there was a significant difference in between 'SON' and 'SOO' (.001)', 'SON' and 'TOS' (.001), 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.001), 'SON' and 'UMA' (.001) 'SON' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on SOO was observed that there was a significant difference in between 'SOO' and 'SON' (.001)', 'SOO' and 'TOS' (.001), 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'OSG' (.001), 'SOO' and 'UMA' (.001) 'SOO' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on TOS was observed that there was a significant difference in between ‘TOS’ and ‘SON’ (.001), ‘TOS’ and ‘SOO’ (.001), ‘TOS’ and ‘OGO’ (.001), ‘TOS’ and ‘HRG’ (.001), ‘TOS’ and ‘KOG’ (.001), ‘TOS’ and ‘OSG’ (.001), ‘TOS’ and ‘UMA’ (.001) ‘TOS’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on OGO was observed that there was a significant difference in between ‘OGO’ and ‘SON’ (.001), ‘OGO’ and ‘SOO’ (.001), ‘OGO’ and ‘TOS’ (.001), ‘OGO’ and ‘HRG’ (.001), ‘OGO’ and ‘KOG’ (.001), ‘OGO’ and ‘OSG’ (.001), ‘OGO’ and ‘UMA’ (.001) ‘OGO’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on HRG was observed that there was a significant difference in between ‘HRG’ and ‘SON’ (.001), ‘HRG’ and ‘SOO’ (.001), ‘HRG’ and ‘TOS’ (.001), ‘HRG’ and ‘OGO’ (.001), ‘HRG’ and ‘KOG’ (.001), ‘HRG’ and ‘OSG’ (.001), ‘HRG’ and ‘UMA’ (.001) ‘HRG’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on KOG was observed that there was a significant difference in between ‘KOG’ and ‘SON’ (.001), ‘KOG’ and ‘SOO’ (.001), ‘KOG’ and ‘TOS’ (.001) ‘KOG’ and ‘OGO’ (.001), ‘OGO’ and ‘HRG’ (.001), ‘KOG’ and ‘OSG’ (.001), ‘KOG’ and ‘UMA’ (.001) ‘KOG’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on OSG was observed that there was a significant difference in between ‘OSG’ and ‘SON’ (.001), ‘OSG’ and ‘SOO’ (.001), ‘OSG’ and ‘TOS’ (.001) ‘OSG’ and ‘OGO’ (.001), ‘OSG’ and ‘HRG’ (.001), ‘OSG’ and ‘KOG’ (.001), ‘OSG’ and ‘UMA’ (.017) ‘OSG’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘SOO’ (.001), ‘UMA’ and ‘TOS’ (.001) ‘UMA’ and ‘OGO’ (.001), ‘UMA’ and ‘HRG’ (.001), ‘UMA’ and ‘KOG’ (.001), ‘UMA’ and ‘OSG’ (.017), ‘UMA’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on OUG was observed that there was a significant difference in between ‘OUG’ and ‘SON’ (.001), ‘OUG’ and ‘SOO’ (.001), ‘OUG’ and ‘TOS’ (.001) ‘OUG’ and ‘OGO’ (.001), ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001), ‘OUG’ and ‘UMA’ (.001) respectively.

### **Findings of the Study**

Comprehending the kinematics of Judo techniques is essential when performing in competition. The focus of this study was to examine how judo techniques and body weight associated. In order to do this, a qualitative approach was taken, data was incorporated, and a video analysis was used.

These results offer significant novel knowledge about how different weight categories and judo techniques affect kinematic characteristics. The results by descriptive analysis and the results by multivariate analysis comprise the two main components of the findings. A thorough examination of the data is given in each part, emphasizing the most important patterns, trends, and linkages found.

Overall, the results show prospective for subsequent studies in the fields of biomechanics and judo, and will be of great use to the bio mechanists, judoists, sports scientists, coaches, and sports analysts.

### **Findings by Descriptive Analysis**

The means and standard deviation of dependent variables in the execution of selected judo techniques in accordance with the weight categories have been shown in Table 7 and it is found that the mean score is different in different weight categories.

The means and standard deviation of kinematic variables in the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in Table 11 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories.

The mean value of kinematic variable Angular velocity corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 35 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The Angular Velocity seems predominant in Hand Techniques, were as light weight categories shows higher mean value as compared to the other weight categories.

The mean value of kinematic variable Angular Displacement corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 36 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Angular Displacement shows higher in hip techniques as well as leg techniques among the heavy weight categories.

The mean value of kinematic variable Movement Time corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 37 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Movement Time was higher in Heavy Weight categories corresponding to the Tachi Waza classification where as the light weight categories the mean value seems lesser.

The mean value of kinematic variable Height of Center of gravity corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 38 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. Mean value of Height of Center of gravity was higher in heavy weight categories, were as mean value of Height of Center of gravity was lesser in light weight categories.

The mean value of kinematic variable Angle Hip Joint corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 39 and it is found that the mean score is different

in the Tachi Waza Classification of judo techniques accordance with weight categories. Mean value of Angle of Hip Flexion was Obtuse Angles in Heavy weight categories as compared to the other weight categories. Whereas in light weight categories shows acute angle values corresponding to Hip techniques.

The mean value of kinematic variable Angle of knee flexion corresponding to the Tachi Waza classification of selected techniques in accordance with the weight categories have been shown in figure 40 and it is found that the mean score is different in the Tachi Waza Classification of judo techniques accordance with weight categories. The mean value of Angle of knee flexion comes as Acute angles corresponding to hand techniques in accordance with light weight categories.

The means and standard deviation of angular velocity in the execution of selected techniques in accordance with the weight categories have been shown in Table 16 and it is found that the mean score is different in different weight categories

The means and standard deviation of Angular Displacement in the execution of selected techniques in accordance with the weight categories have been shown in Table 19 and it is found that the mean score is different in different weight categories

The means and standard deviation of Movement Time in the execution of selected techniques in accordance with the weight categories have been shown in Table 22 and it is found that the mean score is different in different weight categories

The means and standard deviation of Height of Center of Gravity (CoG) in the execution of selected techniques in accordance with the weight categories have been shown in Table 24 and it is found that the mean score is different in different weight categories

The means and standard deviation of Angle of Hip Flexion in the execution of selected techniques in accordance with the weight categories have been shown in Table 28 and it is found that the mean score is different in different weight categories

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The means and standard deviation of Angle of knee flexion in the execution of selected techniques in accordance with the weight categories have been shown in Table 31 and it is found that the mean score is different in different weight categories.

### **Findings by Univariate and Multivariate Analysis**

The results of MANOVA were presented in the Table 7 It reveals that, the calculated Pillai's trace F value of Weight Categories was 236.527, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{01}$  for weight categories (Between Groups) were failed to accept. The calculated Pillai's trace F value of selected judo techniques was 32.835, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{02}$  for weight categories (Between Groups) were failed to accept. The statistical results shows that there is a significant interaction between competition weight categories and selected judo techniques with Pillai's trace F value 19.302 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{03}$  for weight categories (Between Groups) were failed to accept.

As the statistical results revealed that there is significant difference, further analysis is needed to explain which level of category makes the difference. Tukey's Post Hoc analysis is used to explain the difference. The result of the analysis is shown in the Table 10 which shows the Tukey's Post Hoc result for the kinematic variables among three weight categories.

For the Angular Velocity, It was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and "Middle weights' and 'Heavy weights' (.001).

For the Angular Displacement among three weight categories. It was observed that there is no significant difference between 'Light weights' and 'Middle weights'

(.168), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Movement Time, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Height of CoG, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Mid weights' and 'Heavy weights' (.001).

For the Angle of Hip flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Mid weights' and 'Heavy weights' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

The results of MANOVA were presented in the Table 13 It reveals that, the calculated Pillai's trace F value of Weight Categories was 178.114, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{04}$  for weight categories (Between Groups) were failed to accept. The calculated Pillai's trace F value of classification of selected judo techniques was 56.138, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{05}$  for Tachi Waza classification of judo techniques (Between Groups) were failed to accept. The statistical results shows that there is a significant interaction between competition weight categories and Tachi Waza classification selected judo techniques with Pillai's trace F value 30.695 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{06}$  for the

interaction between weight categories and Tachi Waza classification of judo techniques (Between Groups) were failed to accept.

The result of the analysis is shown in the Table 14, which shows the Tukey's Post Hoc result for the kinematic variables among three weight categories corresponding to the Tachi Waza Classification of Judo Techniques.

For the Angular Velocity, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angular Displacement among three weight categories. It was observed that there is no significant difference between 'Light weights' and 'Middle weights' (.271), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Movement Time, it was observed that there is significant difference between 'Light weights' and 'Middle weight' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Height of CoG, it was observed that there is significant difference between 'Light weights' and 'Middle weights' (.001), between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angle of Hip flexion, it was observed that there is no significant difference between 'Light weights' and 'Middle weights' (.125), whereas there is significant difference between 'Light weights' and 'Heavy weights' (.001), and 'Middle weights' and 'Heavy weights' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Light weights' and 'Middle weight' (.001), between 'Light weights' and 'Heavy weight' (.001), and 'Middle weight' and 'Heavy weights' (.001).

As the multivariate analysis revealed that there is significant difference among Tachi Waza classification of judo techniques, further analysis is needed to explain which classification of judo techniques makes the difference. Tukey's Post Hoc

analysis is used to explain the difference. The result of the analysis is shown in the Table 15, which shows the Tukey's Post Hoc result for the kinematic variables among the Tachi Waza classification of judo techniques Hand Techniques.

For the Angular Velocity, it was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angular Displacement among the Nage Waza. It was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Movement Time, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.244), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Height of CoG, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.075), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angle of Hip flexion, it was observed that there is no significant difference between 'Te Waza' and 'Koshi Waza' (.263), There is significant difference between 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

For the Angle of knee flexion, it was observed that there is significant difference between 'Te Waza' and 'Koshi Waza' (.001), 'Te Waza' and 'Ashi Waza' (.001), and 'Koshi Waza' and 'Ashi Waza' (.001).

The results of the Two-way ANOVA were presented in the Table 17. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Velocity. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference

among the selected Judo techniques with regard to the Angular Velocity. The calculated F value of interaction between Weight Categories and Judo Techniques 66.296 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_0$  was failed to support.

Post Hoc result for the Angular Velocity on SON was observed that there was a significant difference between 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.019), 'SON', 'SON' and 'UMA' (.001), whereas there was no significant difference in between 'SON' and 'SOO' (.257), between 'SON' and 'TOS' (.972), 'SON' and 'OUG' (.662),

Post Hoc result for the Angular Velocity on SOO was observed that there was a significant difference between 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'UMA' (.001), whereas there was no significant difference in between 'SOO' and 'SON' (.257), between 'SOO' and 'TOS' (.917), 'SOO' and 'OSG' (.987), 'SOO' and 'OUG' (.999).

Post Hoc result for the Angular Velocity on TOS was observed that there was a significant difference between 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'UMA' (.001), whereas there was no significant difference in between 'TOS' and 'SOO' (.917), between 'TOS' and 'SON' (.972), 'TOS' and 'OUG' (.999), 'TOS' and 'OSG' (.327),

Post Hoc result for the Angular Velocity on OGO was observed that there was a significant difference between 'OGO' and 'SON' (.001), 'OGO' and 'SOO' (.001), 'OGO' and 'TOS' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001) Whereas there was no significant difference in between 'OGO' and 'HRG' (1.000), 'OGO' and 'KOG' (.846), 'OGO' and 'UMA' (.323).

Post Hoc result for the Angular Velocity on HRG was observed that there was significant difference in between 'HRG' and 'SON' (.001), 'HRG' and 'SOO' (.001), 'HRG' and 'TOS' (.001), 'HRG' and 'OSG' (.001) 'HRG' and 'OUG' (.001), whereas there was no significant difference in between 'HRG' and 'OGO' (1.000), 'HRG' and 'KOG' (1.000), 'HRG' and 'UMA' (.106).

Post Hoc result for the Angular Velocity on KOG was observed that there was significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'SOO' (.001) 'KOG' and 'TOS' (.001) 'KOG' and 'OUG' (.001), 'KOG' and 'OSG' (.001), whereas there was no significant difference in between 'KOG' and 'OGO' (.8461), 'KOG' and 'HRG' (.522), 'KOG' and 'UMA' (.996).

Post Hoc result for the Angular Velocity on OSG was observed that there was a significant difference in between 'OSG' and 'SON' (.019), 'OSG' and 'OGO' (.001), 'OSG' and 'HRG' (.001), 'OSG' and 'KOG' (.001), 'OSG' and 'UMA' whereas there was no significant difference in between 'OSG' and 'SON' (.019), 'OSG' and 'SOO' (.987), 'OSG' and 'TOS' (.327), 'OSG' and 'OUG' (.795).

Post Hoc result for the Angular Velocity on UMA was observed that there was a significant difference in between 'UMA' and 'SON' (.001), 'UMA' and 'SOO' (.001), 'UMA' and 'TOS' (.001), 'UMA' and 'OSG' (.001), 'UMA' and 'OUG' (.001), whereas there was no significant difference in between 'UMA' and 'OGO' (.323), 'UMA' and 'HRG' (.106), 'UMA' and 'KOG' (.996).

Post Hoc result for the Angular Velocity on OUG was observed that there was a significant difference in between 'OUG' and 'OGO' (.001), 'OUG' and 'HRG' (.001), 'OUG' and 'KOG' (.001), 'OUG' and 'UMA' (.001), whereas there was no significant difference 'OUG' and 'SON' (.662), 'OUG' and 'SOO' (.999), 'OUG' and 'TOS' (.999), 'OUG' and 'OSG' (.795).

The results of Two-way ANOVA were presented in the Table 20. It reveals that, the calculated F value of Weight Categories was 361.341 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Displacement. The calculated F value of selected Judo Techniques was 31.479, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angular Displacement. The calculated F value of interaction between Weight Categories and Judo Techniques 37.783 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{08}$  was failed to support.

Post Hoc result for the Angular Displacement on SON was observed that there was a significant difference in between 'SON' and 'TOS' (.012), 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.002) 'SON' and 'UMA' (.001), whereas there was no significant difference in between 'SON' and 'SOO' (1.000) and 'SON' and OUG' (1.000) respectively.

Post Hoc result for the Angular Displacement on SOO was observed that there was a significant difference in between 'SOO' and 'TOS' (.006), 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'OSG' (.004) 'SOO' and 'UMA' (.001), whereas there was no significant difference in between 'SOO' and 'SON' (1.000) and 'SOO' and OUG' (1.000) respectively.

Post Hoc result for the Angular Displacement on TOS was observed that there was a significant difference in between 'TOS' and 'SON' (.012) 'TOS' and 'SOO' (.006), 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'OSG' (.001) 'TOS' and 'UMA' (.001), 'TOS' and OUG' (.017) respectively.

Post Hoc result for the Angular Displacement on OGO was observed that there was a significant difference in between 'OGO' and 'SON' (.001), 'OGO' and 'SOO' (.001), 'OGO' and 'TOS' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001), whereas there was no significant in between 'OGO' and 'HRG' (.985) and 'OGO' and 'KOG' (.985), 'OUG' and 'UMA' (.944), respectively.

Post Hoc result for the Angular Displacement on HRG was observed that there was a significant difference in between 'HRG' and 'SON' (.001), 'HRG' and 'SOO' (.001), 'HRG' and 'TOS' (.001), 'HRG' and 'OSG' (.001), 'HRG' and 'OUG' (.001), whereas there was no significant difference in between 'HRG' and 'OGO' (.985) and 'HRG' and 'KOG' (1.000), 'HRG' and 'UMA' (1.000), respectively.

Post Hoc result for the Angular Displacement on KOG was observed that there was a significant difference in between 'KOG' and 'SON' (.001), 'KOG' and 'SOO' (.001), 'KOG' and 'TOS' (.001), 'KOG' and 'OSG' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'OGO' (.985) and

‘KOG’ and ‘HRG’ (1.000), ‘KOG’ and ‘UMA’ (1.000), respectively.

Post Hoc result for the Angular Displacement on OSG was observed that there was a significant difference in between ‘OSG’ and ‘SON’ (.002), ‘OSG’ and ‘SOO’ (.004), ‘OSG’ and ‘TOS’ (.001) ‘OSG’ and ‘OGO’ (.008), ‘OSG’ and ‘HRG’ (.001), ‘OSG’ and ‘KOG’ (.001), ‘OSG’ and ‘UMA’ (.001), ‘OSG’ and OUG’ (.001) respectively.

Post Hoc result for the Angular Displacement on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘SOO’ (.001), ‘UMA’ and ‘TOS’ (.001), ‘UMA’ and ‘OSG’ (.001), ‘UMA’ and ‘OUG’ (.001), whereas there was no significant difference in between ‘UMA’ and ‘OGO’ (.944) and ‘UMA’ and ‘HRG’ (1.000), ‘UMA’ and ‘KOG’ (1.000), respectively.

Post Hoc result for the Angular Displacement on OUG was observed that there was a significant difference in between, ‘OUG’ and ‘TOS’ (.017), ‘OUG’ and ‘OGO’ (.001) and ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001), ‘OUG’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OUG’ and ‘SON’ (1.000), ‘OUG’ and ‘SOO’ (1.000) respectively.

The results of the Two-way ANOVA were presented in the Table 23. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Movement Time. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Movement Time. The calculated F value of interaction between Weight Categories and Judo Techniques 62.221 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{09}$  failed to support.

Post Hoc result for the Movement Time on SON was observed that there was a significant difference in between ‘SON’ and ‘KOG’ (.001), ‘SON’ and ‘OSG’

(.033) ‘SON’ and ‘UMA’ (.001), ‘SON’ and OUG’ (.033) whereas there was no significant difference in between ‘SON’ and ‘SOO’ (.085)’, ‘SON’ and ‘TOS’ (.085), ‘SON’ and ‘OGO’ (.085), ‘SON’ and ‘HRG’ (.929) respectively.

Post Hoc result for the Movement Time on SOO was observed that there was a significant difference in between ‘SOO’ and ‘OSG’ (.001), ‘SOO’ and OUG’ (.001) whereas there was no significant difference in between ‘SOO’ and ‘SON’ (.085)’, ‘SOO’ and ‘TOS’ (1.000), ‘SOO’ and ‘OGO’ (1.000), ‘SOO’ and ‘HRG’ (.787), ‘SOO’ and ‘KOG’ (.263), ‘SOO’ and ‘UMA’ (.787) respectively.

Post Hoc result for the Movement Time on TOS was observed that there was a significant difference in between ‘TOS’ and ‘OSG’ (.001), ‘TOS’ and OUG’ (.001) whereas there was no significant difference in between ‘TOS’ and ‘SON’ (.085)’, ‘TOS’ and ‘SOO’ (1.000), ‘TOS’ and ‘OGO’ (1.000), ‘TOS’ and ‘HRG’ (.787), ‘TOS’ and ‘KOG’ (.263), ‘TOS’ and ‘UMA’ (.787) respectively.

Post Hoc result for the Movement Time on OGO was observed that there was a significant difference in between ‘OGO’ and ‘OSG’ (.001), ‘OGO’ and OUG’ (.001) whereas there was no significant difference in between ‘OGO’ and ‘SON’ (.085)’, ‘OGO’ and ‘SOO’ (1.000), ‘OGO’ and ‘TOS’ (1.000), ‘OGO’ and ‘HRG’ (.787), ‘OGO’ and ‘KOG’ (.263), ‘OGO’ and ‘UMA’ (.787) respectively.

Post Hoc result for the Movement Time on HRG was observed that there was a significant difference in between ‘HRG’ and ‘KOG’ (.002), ‘HRG’ and ‘OSG’ (.001) ‘HRG’ and ‘UMA’ (.033), ‘HRG’ and OUG’ (.001) whereas there was no significant difference in between ‘HRG’ and ‘SON’ (.929)’, ‘HRG’ and ‘SOO’ (.787)’, ‘HRG’ and ‘TOS’ (.787), ‘HRG’ and ‘OGO’ (.787) respectively.

Post Hoc result for the Movement Time on KOG was observed that there was a significant difference in between ‘KOG’ and ‘SON’ (.001), ‘KOG’ and ‘HRG’ (.002), ‘KOG’ and ‘OSG’ (.001), ‘KOG’ and ‘OUG’ (.001), whereas there was no significant difference in between ‘KOG’ and ‘SOO’ (.263)’, ‘KOG’ and ‘TOS’ (.263)’, ‘KOG’ and ‘OGO’ (.985)’, ‘KOG’ and ‘UMA’ (.996) respectively.

Post Hoc result for the Movement Time on OSG was observed that there was a significant difference in between OSG and ‘SON’ (.033), OSG and ‘SOO’ (.001), OSG and ‘TOS’ (.001), OSG and ‘OGO’ (.001), OSG and ‘HRG’ (.001), OSG and ‘KOG’ (.001), OSG and ‘UMA’ (.001), whereas there was no significant difference among in between ‘OSG and ‘OUG’ (1.000) respectively.

Post Hoc result for the Movement Time on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘HRG’ (.033), ‘UMA’ and ‘OSG’ (.001), ‘UMA’ and ‘OUG’ (.001), whereas there was no significant difference in between ‘UMA’ and ‘SOO’ (.787) and ‘UMA’ and ‘TOS’ (.787), ‘UMA’ and ‘OGO’ (.787), ‘UMA’ and ‘KOG’ (.996) respectively.

Post Hoc result for the Movement Time on OUG was observed that there was a significant difference in between, ‘OUG’ and ‘SON’ (.033), ‘OUG’ and ‘SOO’ (.001) and ‘OUG’ and ‘TOS’ (.001), ‘OUG’ and ‘OGO’ (.001), ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OUG’ and ‘OSG’ (1.000) respectively.

The results of the Two-way ANOVA were presented in the Table 26. It reveals that, the calculated F value of Weight Categories was 2477.015, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to Height of Center of Gravity (CoG). The calculated F value of selected judo techniques was 50.139 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Height of Center of Gravity (CoG). The calculated F value of interaction between Weight Categories and Judo Techniques 10.499 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{10}$  failed to support.

Post Hoc result for the Height of Center of Gravity on SON was observed that there was a significant difference in between ‘SON’ and ‘SOO’ (.001), ‘SON’ and ‘OGO’ (.001), ‘SON’ and ‘KOG’ (.001), ‘SON’ and ‘UMA’ (.001), ‘SON’ and ‘OUG’ (.001) whereas there was no significant difference in between, ‘SON’ and ‘TOS’ (1.000), ‘SON’ and ‘HRG’ (1.000), ‘SON’ and ‘OSG’ (.117) respectively.

Post Hoc result for the Height of Center of Gravity on SOO was observed that there was a significant difference in between ‘SOO’ and ‘SON’ (.001) ‘SOO’ and ‘TOS’ (.001), ‘SOO’ and ‘OGO’ (.002), ‘SOO’ and ‘HRG’ (.001), ‘SOO’ and ‘OSG’ (.001), ‘SOO’ and ‘UMA’ (.001), ‘SOO’ and OUG’ (.001) , whereas there was no significant difference in between ‘SOO’ and ‘KOG’ (.999) respectively.

Post Hoc result for the Height of Center of Gravity on TOS was observed that there was a significant difference in between ‘TOS’ and ‘SOO’ (.001), ‘TOS’ and ‘OGO’ (.001), ‘TOS’ and ‘KOG’ (.001), ‘TOS’ and ‘OSG’ (.028), ‘TOS’ and ‘UMA’ (.001), ‘TOS’ and OUG’ (.006) whereas there was no significant difference in between ‘TOS’ and ‘SON’ (1.000) ‘TOS’ and ‘HRG’ (.999) respectively.

Post Hoc result for the Height of Center of Gravity on OGO was observed that there was a significant difference in between ‘OGO’ and ‘SON’ (.001), ‘OGO’ and ‘SOO’ (.002), ‘OGO’ and ‘TOS’ (.001), ‘OGO’ and ‘HRG’ (.001), ‘OGO’ and ‘KOG’ (.001) , ‘OGO’ and ‘OSG’ (.001) ‘OGO’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OGO’ and OUG’ (.733) respectively.

Post Hoc result for the Height of Center of Gravity on HRG was observed that there was a significant difference in between ‘HRG’ and ‘SOO’ (.001) ‘HRG’ and ‘OGO’ (.001), ‘HRG’ and ‘KOG’ (.001), ‘HRG’ and ‘UMA’ (.001), ‘HRG’ and OUG’ (.001) whereas there was no significant difference in between ‘HRG’ and ‘SON’ (1.000), ‘HRG’ and ‘TOS’ (.999), ‘HRG’ and ‘OSG’ (.189) respectively.

Post Hoc result for the Height of Center of Gravity on KOG was observed that there was a significant difference in between ‘KOG’ and ‘SON’ (.001), ‘KOG’ and ‘TOS’ (.001), ‘KOG’ and ‘OGO’ (.001), ‘KOG’ and ‘HRG’ (.001), ‘KOG’ and ‘OSG’ (.001), ‘KOG’ and ‘UMA’ (.001), ‘KOG’ and ‘OUG’ (.001), whereas there was no significant difference in between ‘KOG’ and ‘SOO’ (.999) respectively.

Post Hoc result for the Height of Center of Gravity on OSG was observed that there was a significant difference in between OSG and ‘SOO’ (.001), OSG and ‘TOS’ (.028), OSG and ‘OGO’ (.001), OSG and ‘KOG’ (.001), OSG and ‘OUG’ (.001), whereas there was no significant difference in between OSG and ‘SON’ (.117), ‘OSG’ and ‘HRG’ (.189), OSG and ‘UMA’ (.479) respectively.

Post Hoc result for the Height of Center of Gravity on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘SOO’ (.001) and ‘UMA’ and ‘TOS’ (.001), ‘UMA’ and ‘OGO’ (.001), ‘UMA’ and ‘KOG’ (.001), ‘UMA’ and ‘HRG’ (.001), ‘UMA’ and ‘OUG’ (.001) whereas there was no significant difference in between ‘UMA’ and ‘OSG’ (.479) respectively.

Post Hoc result for the Height of Center of Gravity on OUG was observed that there was a significant difference in between, ‘OUG’ and ‘SON’ (.001), ‘OUG’ and ‘SOO’ (.001) and ‘OUG’ and ‘TOS’ (.006), ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001) ‘OUG’ and ‘UMA’ (.001), whereas there was no significant difference in between ‘OUG’ and ‘OGO’ (.733), respectively.

The results of the Two-way ANOVA are presented in the Table 29. It reveals that, the calculated F value of Weight Categories was 246.309, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of Hip Joint. The calculated F value of selected judo techniques was 652.736, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angle of Hip Joint. The calculated F value of interaction between Weight Categories and Judo Techniques 18.249 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{11}$  failed to support.

Post Hoc result for the Angle of Hip Flexion on SON was observed that there was a significant difference in between ‘SON’ and ‘TOS’ (.001), ‘SON’ and ‘HRG’ (.001), ‘SON’ and ‘OSG’ (.001) , ‘SON’ and ‘OUG’ (.001), whereas there was no significant difference in between, ‘SON’ and ‘SOO’ (.990), ‘SON’ and ‘OGO’ (.998), ‘SON’ and ‘KOG’ (1.000) ‘SON’ and ‘UMA’ (.807), respectively.

Post Hoc result for the Angle of Hip Flexion on SOO was observed that there was a significant difference in between ‘SOO’ and ‘TOS’ (.001), ‘SOO’ and ‘HRG’ (.001), ‘SOO’ and ‘OSG’ (.001) , ‘SOO’ and OUG’ (.001), whereas there was no significant difference in between ‘SOO’ and ‘SON’ (.990) ‘SOO’ and ‘OGO’ (1.00), ‘SOO’ and ‘KOG’ (.999), ‘SOO’ and ‘UMA’ (.999) respectively.

Post Hoc result for the Angle of Hip Flexion on TOS was observed that there was a significant difference in between 'TOS' and 'SON' (.001), 'TOS' and 'SOO' (.001), 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'OSG' (.030), 'TOS' and 'UMA' (.001), whereas there was no significant difference in between 'TOS' and 'OUG' (.0891) respectively.

Post Hoc result for the Angle of Hip Flexion on OGO was observed that there was a significant difference in between 'OGO' and 'TOS' (.001), 'OGO' and 'HRG' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'OUG' (.001) whereas there was no significant difference in between 'OGO' and 'SON' (.998), 'OGO' and 'SOO' (1.000), 'OGO' and 'KOG' (1.000) 'OGO' and 'UMA' (.994), respectively.

Post Hoc result for the Angle of Hip Flexion on HRG was observed that there was a significant difference in between 'HRG' and 'SON' (.001), 'HRG' and 'SOO' (.001) 'HRG' and 'TOS' (.001) 'HRG' and 'OGO' (.001), 'HRG' and 'KOG' (.001), 'HRG' and 'OSG' (.189) 'HRG' and 'UMA' (.001), 'HRG' and OUG' (.001) respectively.

Post Hoc result for the Angle of Hip Flexion on KOG was observed that there was a significant difference in between 'KOG' and 'TOS' (.001), 'KOG' and 'HRG' (.001), 'KOG' and 'OSG' (.001), 'KOG' and 'HRG' (.001), 'KOG' and 'OUG' (.001), 'KOG' and 'OUG' (.001), whereas there was no significant difference in between 'KOG' and 'SON' (1.000), 'KOG' and 'SOO' (.999) 'KOG' and 'OGO' (1.000) 'KOG' and 'UMA' (.916) respectively.

Post Hoc result for the Angle of Hip Flexion on OSG was observed that there was a significant difference in between 'OSG' and 'SON' (.001), 'OSG' and 'SOO' (.001), 'OSG' and 'TOS' (.030), 'OSG' and 'OGO' (.001), 'OSG' and 'HRG' (.001), 'OSG' and 'KOG' (.001), 'OSG' and 'UMA' (.001), 'OSG' and 'OUG' (.001) respectively.

Post Hoc result for the Angle of Hip Flexion on UMA was observed that there was a significant difference in between 'UMA' and 'TOS' (.001), 'UMA' and 'HRG'

(.001) 'UMA' and 'OSG' (.001), 'UMA' and 'OUG' (.001) whereas there was no significant difference in between 'UMA' and 'SON' (.807), 'UMA' and 'SOO' (.999) 'UMA' and 'OGO' (.994), 'UMA' and 'KOG' (.916) 'UMA' and 'OSG' (.479) respectively.

Post Hoc result for the Angle of Hip Flexion on OUG was observed that there was a significant difference in between, 'OUG' and 'SON' (.001), 'OUG' and 'SOO' (.001), 'OUG' and 'OGO' (.001), 'OUG' and 'HRG' (.001), 'OUG' and 'KOG' (.001), 'OUG' and 'OSG' (.001) 'OUG' and 'UMA' (.001), whereas there was no significant difference in between 'OUG' and 'TOS' (.891), respectively.

The results of the Two-way ANOVA were presented in the Table 32. It reveals that, the calculated F value of Weight Categories was 3981.507, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of knee flexion. The calculated F value of selected judo techniques was 4117.592, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angle of knee flexion. The calculated F value of interaction between Weight Categories and Judo Techniques 59.720 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{12}$  failed to support.

Post Hoc result for the Angle of knee flexion on SON was observed that there was a significant difference in between 'SON' and 'SOO' (.001)', 'SON' and 'TOS' (.001), 'SON' and 'OGO' (.001), 'SON' and 'HRG' (.001), 'SON' and 'KOG' (.001), 'SON' and 'OSG' (.001), 'SON' and 'UMA' (.001) 'SON' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on SOO was observed that there was a significant difference in between 'SOO' and 'SON' (.001)', 'SOO' and 'TOS' (.001), 'SOO' and 'OGO' (.001), 'SOO' and 'HRG' (.001), 'SOO' and 'KOG' (.001), 'SOO' and 'OSG' (.001), 'SOO' and 'UMA' (.001) 'SOO' and 'OUG' (.001),

respectively.

Post Hoc result for the Angle of knee flexion on TOS was observed that there was a significant difference in between 'TOS' and 'SON' (.001)', 'TOS' and 'SOO' (.001), 'TOS' and 'OGO' (.001), 'TOS' and 'HRG' (.001), 'TOS' and 'KOG' (.001), 'TOS' and 'OSG' (.001), 'TOS' and 'UMA' (.001) 'TOS' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on OGO was observed that there was a significant difference in between 'OGO' and 'SON' (.001)', 'OGO' and 'SOO' (.001), 'OGO' and 'TOS' (.001), 'OGO' and 'HRG' (.001), 'OGO' and 'KOG' (.001), 'OGO' and 'OSG' (.001), 'OGO' and 'UMA' (.001) 'OGO' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on HRG was observed that there was a significant difference in between 'HRG' and 'SON' (.001)', 'HRG' and 'SOO' (.001), 'HRG' and 'TOS' (.001), 'HRG' and 'OGO' (.001), 'HRG' and 'KOG' (.001), 'HRG' and 'OSG' (.001), 'HRG' and 'UMA' (.001) 'HRG' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on KOG was observed that there was a significant difference in between 'KOG' and 'SON' (.001)', 'KOG' and 'SOO' (.001), 'KOG' and 'TOS' (.001) 'KOG' and 'OGO' (.001), 'OGO' and 'HRG' (.001), 'KOG' and 'OSG' (.001), 'KOG' and 'UMA' (.001) 'KOG' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on OSG was observed that there was a significant difference in between 'OSG' and 'SON' (.001)', 'OSG' and 'SOO' (.001), 'OSG' and 'TOS' (.001) 'OSG' and 'OGO' (.001), 'OSG' and 'HRG' (.001), 'OSG' and 'KOG' (.001), 'OSG' and 'UMA' (.017) 'OSG' and 'OUG' (.001), respectively.

Post Hoc result for the Angle of knee flexion on UMA was observed that there was a significant difference in between ‘UMA’ and ‘SON’ (.001), ‘UMA’ and ‘SOO’ (.001), ‘UMA’ and ‘TOS’ (.001) ‘UMA’ and ‘OGO’ (.001), ‘UMA’ and ‘HRG’ (.001), ‘UMA’ and ‘KOG’ (.001), ‘UMA’ and ‘OSG’ (.017), ‘UMA’ and ‘OUG’ (.001), respectively.

Post Hoc result for the Angle of knee flexion on OUG was observed that there was a significant difference in between ‘OUG’ and ‘SON’ (.001), ‘OUG’ and ‘SOO’ (.001), ‘OUG’ and ‘TOS’ (.001) ‘OUG’ and ‘OGO’ (.001), ‘OUG’ and ‘HRG’ (.001), ‘OUG’ and ‘KOG’ (.001), ‘OUG’ and ‘OSG’ (.001), ‘OUG’ and ‘UMA’ (.001) respectively.

### **Discussion on Findings**

The kinematic analysis of judo techniques in this study revealed significant insights into the execution of movements across various competition weight categories and specific judo techniques. Six key kinematic variables—angular velocity, angular displacement, movement time, height of the center of gravity, Angle of Hip flexion and Angle of Knee Flexion were meticulously examined, yielding valuable findings. The study underscored that these variables exhibit noteworthy discrepancies in accordance with competition weight categories and the selection of judo techniques. This highlights the nuanced nature of movement execution in judo, where factors such as weight class and technique choice profoundly influence kinematic parameters.

The observed differences in Kinematic variables as follows

- **Angular Velocity:** The analysis of angular velocity in judo techniques revealed significant variations across different competition weight categories and selected techniques. This suggests that the speed at which various movements are executed plays a crucial role in the effectiveness and efficiency of the techniques, highlighting the importance of timing and explosiveness in judo performance.

- **Angular Displacement:** The findings regarding angular displacement demonstrate notable differences between weight categories and specific techniques. This indicates that the range of motion in joints during judo movements varies significantly depending on factors such as body size, strength, and skill level. Understanding these variations can aid coaches and athletes in optimizing technique execution for maximum effectiveness.
- **Movement Time:** The analysis of movement time elucidates distinct patterns across competition weight categories and judo techniques. This emphasizes the importance of timing and rhythm in judo, as well as the efficiency of movement execution. Athletes and coaches can utilize this information to refine training strategies and improve performance through enhanced temporal coordination.
- **Height of Center of Gravity:** The variation in the height of the center of gravity across different weight categories and techniques underscores the dynamic nature of judo movements. This variable reflects the balance and stability of athletes during technique execution, with implications for both offensive and defensive strategies. Understanding how the center of gravity fluctuates can inform training methods aimed at enhancing stability and control in various competitive situations.
- **Angle of Hip Flexion:** The analysis of hip flexion angles highlights significant differences associated with competition weight categories and selected techniques. Hip flexibility and mobility are crucial factors in judo performance, influencing the execution of throws, sweeps, and ground techniques. These findings underscore the importance of flexibility training and technique refinement tailored to individual body characteristics and competitive goals.
- **Angle of Knee Flexion:** The examination of knee flexion angles reveals distinct variations across weight categories and techniques, reflecting differences in stance, posture, and movement mechanics. Optimal knee flexion

is essential for generating power, maintaining balance, and minimizing the risk of injury during judo manoeuvres.

These findings offer valuable insights for coaches, athletes, and researchers seeking to deepen their understanding of judo biomechanics and optimize performance strategies.

### Discussion of Hypotheses

The research scholar formulated the following research hypothesis and statistical hypothesis for this study. The analysis and results have directed to the following decisions for the hypothesis being formulated. For conciseness, the discussion on the formulated hypotheses has been neatly split into two main sections. Discussion on Research Hypothesis and Discussion on statistical Hypotheses.

**Table 34**

*Testing of Hypotheses*

Sl No	Research Hypotheses	Tool Used	Result
1	<i>H<sub>1</sub>: The Weight Categories has significant influences on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships.</i>	Two-way MANOVA	Accepted
2	<i>H<sub>2</sub>: The selected Judo Techniques has significant influences on kinematic variables with respect to the weight categories in the execution of selected judo techniques at the All-India Interuniversity level judo championships.</i>	Two-way MANOVA	Accepted
3	<i>H<sub>3</sub>: There is a significant interaction between Weight Categories and Judo Techniques on Kinematic Variables in the execution of selected judo techniques at All-India Interuniversity level judo championships.</i>	Two-way ANOVA	Accepted

Sl No	Statistical Hypotheses	Tool Used	Result
1	<i>H<sub>01</sub>: There is no significant difference in kinematic variables in accordance with competition weight categories</i>	Two-way MANOVA	Failed to Accept
2	<i>H<sub>02</sub>: There is no significant difference in kinematic variables in accordance with selected Judo Techniques</i>	Two-way MANOVA	Failed to Accept
3	<i>H<sub>03</sub>: There is no significant interaction on kinematic variables in between the weight categories and selected Judo Techniques</i>	Two-way MANOVA	Failed to Accept
4	<i>H<sub>04</sub>: There is no significant difference in Kinematic Variables among competition weight categories corresponding to the Tachi Waza classification of judo techniques.</i>	Two-way MANOVA	Failed to Accept
5	<i>H<sub>05</sub>: There is no significant difference in Kinematic Variables among the Tachi Waza classification of Judo techniques, Te Waza, Koshi Waza &amp; Ashi Waza respectively accordance with weight categories.</i>	Two-way MANOVA	Failed to Accept
6	<i>H<sub>06</sub>: There is no significant interaction on kinematic variables in between the weight categories and Tachi Waza classification of Judo Techniques</i>	Two-way MANOVA	Failed to Accept
7	<i>H<sub>07</sub>: There is no significant difference in Angular Velocity in accordance competition weight categories among selected Judo Techniques.</i>	Two-way ANOVA	Failed to Accept
8	<i>H<sub>08</sub>: There is no significant difference in Angular Displacement in accordance competition weight categories among selected Judo Techniques</i>	Two-way ANOVA	Failed to Accept
9	<i>H<sub>09</sub>: There is no significant difference in Movement Time Velocity in accordance competition weight categories among selected Judo Techniques</i>	Two-way ANOVA	Failed to Accept
10	<i>H<sub>10</sub>: There is no significant difference in Height of CoG in accordance competition weight categories among selected Judo Techniques</i>	Two-way ANOVA	Failed to Accept
11	<i>H<sub>11</sub>: There is no significant difference in Angle of Hip Flexion in accordance competition weight categories among selected Judo Techniques</i>	Two-way ANOVA	Failed to Accept
12	<i>H<sub>12</sub>: There is no significant difference in Angle of knee flexion in accordance competition weight categories among selected Judo Techniques</i>	Two-way ANOVA	Failed to Accept

Based on the results of the statistical analysis, it is evident that the competition category has a substantial impact on the Kinematic variables of the selected Judo Techniques. This implies that athletes competing in different categories may need to adapt their training and technique execution to accommodate for these variations in Kinematic Variables. Understanding these differences can aid coaches and trainers in devising more tailored and specific training programs for athletes based on their competition category. Additionally, further research could delve into the specific factors contributing to these differences in Kinematic Variables and how they may be addressed in the context of Judo training and performance. Furthermore, these findings highlight the importance of considering the competition category when analysing and evaluating Judo performance. The acceptance of all three Research hypotheses at the 0.05 level of significance indicates that there are significant relationships between weight categories, selected judo techniques, and kinematic variables in the execution of judo techniques at the All-India Interuniversity level judo championships.

### **Discussion on Research Hypotheses**

**Hypothesis 1** suggests that weight categories influence kinematic variables during the execution of judo techniques. This finding aligns with previous research in judo, which has shown that athletes in different weight categories may exhibit variations in technique execution due to differences in body size, strength, and agility (**Gunnar Mathisen, 2015**). Weight categories can affect an athlete's center of gravity, balance, and leverage, all of which are critical factors in executing judo techniques effectively. Thus, the acceptance of this hypothesis underscores the importance of considering weight categories when analysing kinematic variables in judo performance.

**Hypothesis 2** posits that selected judo techniques influence kinematic variables differently across weight categories. This finding suggests that certain techniques may be more suited to specific weight categories, or that athletes in different weight categories may adopt variations in technique execution to accommodate their physical attributes. Previous studies have identified technique-

specific biomechanical differences in judo, such as variations in joint angles, force application, and timing, which may contribute to differences in kinematic variables across techniques (**Takanori Ishii,2014**). Therefore, understanding the interaction between technique selection and weight categories is crucial for optimizing training and performance strategies in judo.

**Hypothesis 3** proposes that there is a significant interaction between weight categories and judo techniques on kinematic variables. This finding suggests that the influence of weight categories on kinematic variables may vary depending on the specific judo technique being performed. For example, larger athletes were relying more on strength and power in certain techniques, while smaller athletes were emphasizing speed and agility in others. This interaction underscores the complexity of judo performance and highlights the importance of considering multiple factors, such as athlete characteristics and technical proficiency, when analysing kinematic data in judo (**Thorben Menrad,2021**).

The acceptance of all the hypotheses provides valuable insights into the relationships between weight categories, selected judo techniques, and kinematic variables in judo performance at the All-India Interuniversity level championships. By understanding these relationships, coaches and athletes can tailor training programs and competition strategies to optimize performance outcomes across different weight categories and judo techniques.

### **Discussion on statistical Hypotheses**

Overall, this investigation's statistical tests of hypotheses offers insightful information on the kinematic variables impacting how Judo techniques are performed in competition. These results can act as a starting point for more in-depth studies in the area, which might result in the creation of focused training plans that aid in the growth of accomplished Judo competitors. The statistical hypothesis testing results make it clear that kinematics is essential to the successful use of strategies in line with competitive weight categories. This emphasizes the significance of kinematics, the

addition of weight categories for competition, and the use of particular judo techniques. The statistical test results were traced below

The statistical null hypothesis  $H_{01}$  stated that, there is no significant difference in kinematic variables in accordance with competition weight categories, the calculated Pillai's trace F value of Weight Categories was 236.527, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{01}$  for weight categories were statistically failed to accept. Hence it was obvious that there is a significant difference in kinematic properties accordance with different weight categories.

The statistical null hypothesis  $H_{02}$  states that, there is no significant difference in kinematic variables in accordance with selected Judo Techniques, the calculated Pillai's trace F value of selected judo techniques was 32.835, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{02}$  for selected judo techniques were failed to accept, hence it was statistically proved that there is significant difference in the kinematic variable while performing a judo techniques accordance with different weight categories.

The statistical null hypothesis  $H_{03}$  states that, there is no significant interaction on kinematic variables in between the weight categories and selected Judo Techniques. The statistical results shows that there is a significant interaction between competition weight categories and selected judo techniques with Pillai's trace F value 19.302 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{03}$  for association of weight categories and judo techniques were statistically failed to accept. Hence it revealed that there is a significant association between weight categories and selected judo techniques.

The statistical null hypothesis  $H_{04}$  states that, there is no significant difference in Kinematic Variables among competition weight categories corresponding to the tachi waza classification of judo techniques. the calculated Pillai's trace F value of

Weight Categories was 178.114, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{04}$  for weight categories between were rejected.

The statistical null hypothesis  $H_{05}$  states that, there is no significant difference in Kinematic Variables among Tachi Waza classification of Judo Techniques Te Waza, Koshi Waza & Ashi Waza respectively. The calculated Pillai's trace F value of classification of selected judo techniques was 56.138, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{05}$  for classification of judo techniques were rejected.

The statistical null hypothesis  $H_{06}$  states that, there is no significant interaction on kinematic variables in between the weight categories and Tachi Waza classification of Judo Techniques. The statistical results shows that there is a significant interaction between competition weight categories and classification selected judo techniques with Pillai's trace F value 30.695 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{06}$  for the interaction between weight categories and classification of judo techniques Between Groups were rejected.

The statistical null hypothesis  $H_{07}$  states that, there is no significant difference in Angular Velocity in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 66.296 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{07}$  failed to support.

The statistical null hypothesis  $H_{08}$  states that, there is no significant difference in Angular Displacement in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 37.783 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{08}$  failed to support.

The statistical null hypothesis  $H_{09}$  states that, there is no significant difference in Movement Time Velocity in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 62.221 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{09}$  failed to support.

The statistical null hypothesis  $H_{10}$  states that, there is no significant difference in Height of CoG in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 10.499 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{10}$  failed to support.

The statistical null hypothesis  $H_{11}$  states that, there is no significant difference in Angle of Hip Flexion in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 18.249 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{11}$  failed to support.

The statistical null hypothesis  $H_{12}$  states that, there is no significant difference in Angle of Knee Flexion in accordance competition categories among selected Judo Techniques. The calculated F value of interaction between Weight Categories and Judo Techniques 59.720 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{12}$  failed to support.

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Chapter V

**SUMMARY AND CONCLUSIONS**

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Summary.....	211
Conclusions.....	213

## **Summary**

The research scholar was motivated to undertake the study entitled “Biomechanical analysis of selected judo techniques: an interpretation of kinematic variables in accordance with competition weight categories” The purpose of the study was to investigate relative importance of selected kinematical factors of selected judo techniques in relation to competitive weight categories. The objectives were to determine the kinematic characteristics of the selected judo techniques. To investigate the Kinematic benefits of the chosen judo techniques. To ascertain the kinematic characteristics of the judo techniques chosen. To determine the influence of weight categories on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships. To investigate the differences in kinematics among the judo techniques chosen with respect to the weight categories in the All-India Interuniversity level judo championships. To quantify the kinematic properties of the judo techniques chosen. To compare specified kinematical characteristics between various weight categories. To determine which judo techniques, offer more kinematic benefits relying on the weight categories.

The study was delimited to the following The research comprised on the collected videos of Judo techniques performed by the participants in All India interuniversity Judo championships from 2017 to 2022. The Judokas participated in all India interuniversity were the subjects of the study for the required practical application of the selected judo techniques ,The analysis was delimited to the selected kinematical variables delimited to the competition weight categories specified by IJF, delimited to the motion capture kit for mechanical analysis. Motion capture kit and

analysis software, meteorological status like atmospheric temperature, humidity etc., during the study period, could not be controlled, The effect of uncontrollable factors such as sudden emotional disturbance of the subjects due to factors other than related to sports was considered as the limitation of the study,

The formulated hypothesized were stated as the Weight Categories has significant influences on kinematic variables with respect to the execution of selected judo techniques in the All-India Interuniversity level judo championships, the selected Judo Techniques has significant influences on kinematic variables with respect to the weight categories in the execution of selected judo techniques at the All-India Interuniversity level judo championships and there is a significant interaction between Weight Categories and Judo Techniques on Kinematic Variables in the execution of selected judo techniques at All-India Interuniversity level judo championships.

The participants in all India interuniversity judo championships held from 2017 to 2022 were subjects for the practical application of selected judo techniques from each of the weight categories specified by the International Judo Federation. Weight categories were utilized in the All India Inter University Championships and World University Competitions held under the auspices of the AIJU, JFI and JFI.

Angular Velocity, Angular Displacement, Movement Time, Height of CoG, Angle of Hip flexion, Angle of Knee flexion were the selected kinematic variables. For video recording, a 16mm camera (Sony high definition/240f/s) was positioned at a distance of 10 meters from the centre of the contest (Technique Performing) area. The throwing area was 10X10 meters and was covered with tatami, a type of Judo mat. The camera was fixed on a tripod and angled at a right angle to the performer's (sagittal plane) plane of movement. The reference axes were fixed bodies positioned in the camera's field of view. The color of the contest mat area for calibration and was filmed in the plane of motion. The frame rate of the high definition camera was set at 240 frames per second. Videos of selected Judo Techniques were recorded and examined in the Biomechanics software tool. The experiment was conducted using an experimental approach before the competition, and camera operators were well informed. This guaranteed that data was collected in a consistent manner was the test

competency. To achieve ideal visual creation, camera setup with a 10 x 10 m viewing volume was used. This viewing volume is large enough to record subject performance. This tool does not require the use of any markers. The camera guy employed under the supervision of scholar to capture the performance of each bout scheduled in the fixture, after which the Referee calls “Hajime” began to capture the bouts and continued until the throwing technique was completed or by the “mate” call by the Referee. The footage was saved on an external hard disc with a different file name for each weight categories for each Throwing Technique. The scholar also collected secondary data of the performance of selected throwing techniques from the available sources.

The collected data has been undergone statistical tests, Box's M test was used to check the equality of multiple variance-covariance matrices, as a result it was obvious that the hypothesis has to be retained and Pillai's trace test produced by a MANOVA was fit to find the significance among the collected data, so that the analysis of data had done by tabulating the data and applying Two-way MANOVA (analysis of Multivariate) to understand and interpret the objectives inline of the findings. The Two-way ANOVA was employed to see if there are any significant differences in a dependent variable between two or more independent groups (Weight categories and Judo techniques). Post Hoc test was administrated for the critical interpretation on kinematical variables in the application of selected judo techniques. All the statistical computations had been done with the SPSS version 23.0.1 software by IBM.

The statistical results of the selected mechanical variables which comprise of angular velocity, angular displacement, movement time, height of CoG, angle of hip flexion, angle of knee flexion leads that the null hypothesis was rejected. The “p” value found significant at 0.05 level of significance in the execution of selected judo techniques in accordance with the weight categories. Hence the research hypothesis was accepted in all the variables.

## Conclusions

After careful examination of the results of the study, the researcher came to the following conclusions.

1. It reveals that, the calculated Pillai's trace F value of Weight Categories was 236.527, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{01}$  for weight categories (Between Groups) were failed to accept.
2. The calculated Pillai's trace F value of selected judo techniques was 32.835, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical null hypothesis  $H_{02}$  for weight categories (Between Groups) were failed to accept.
3. The statistical results shows that there is a significant interaction between competition weight categories and selected judo techniques with Pillai's trace F value 19.302 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{03}$  for weight categories (Between Groups) were failed to accept.
4. It reveals that, the calculated Pillai's trace F value of Weight Categories was 178.114, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{04}$  for weight categories (Between Groups) were failed to accept.
5. The calculated Pillai's trace F value of Tachi Waza classification of selected judo techniques was 56.138, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the kinematic variables. Therefore, the statistical hypothesis  $H_{05}$  for classification of judo techniques (Between Groups) were failed to accept.

6. The statistical results shows that there is a significant interaction between competition weight categories and classification selected judo techniques with Pillai's trace F value 30.695 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{06}$  for the interaction between weight categories and Tachi Waza classification of judo techniques (Between Groups) were failed to accept.
7. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Velocity.
8. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angular Velocity.
9. The calculated F value of interaction between Weight Categories and Judo Techniques 66.296 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_0$  was failed to support.
10. It reveals that, the calculated F value of Weight Categories was 361.341 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angular Displacement.
11. The calculated F value of selected Judo Techniques was 31.479, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angular Displacement.
12. The calculated F value of interaction between Weight Categories and Judo Techniques 37.783 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{08}$  was failed to support.

13. It reveals that, the calculated F value of Weight Categories was 75.125, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Movement Time.
14. The calculated F value of selected judo techniques was 22.598, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Movement Time.
15. The calculated F value of interaction between Weight Categories and Judo Techniques 62.221 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{09}$  failed to support.
16. It reveals that, the calculated F value of Weight Categories was 2477.015, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to Height of Center of Gravity (CoG).
17. The calculated F value of selected judo techniques was 50.139 which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Height of Center of Gravity (CoG).
18. The calculated F value of interaction between Weight Categories and Judo Techniques 10.499 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{10}$  failed to support.
19. It reveals that, the calculated F value of Weight Categories was 246.309, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of Hip Joint.
20. The calculated F value of selected judo techniques was 652.736, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is

significant difference among the selected Judo techniques with regard to the Angle of Hip Joint.

21. The calculated F value of interaction between Weight Categories and Judo Techniques 18.249 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical null hypothesis  $H_{11}$  failed to support.
22. It reveals that, the calculated F value of Weight Categories was 3981.507, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the weight categories with regard to the Angle of knee flexion.
23. The calculated F value of selected judo techniques was 4117.592, which was significant since p value ( $0.001 < 0.05$ ) at 0.05 level, this indicates that there is significant difference among the selected Judo techniques with regard to the Angle of knee flexion.
24. The calculated F value of interaction between Weight Categories and Judo Techniques 59.720 was significant, since p value ( $0.001 < 0.05$ ) at 0.05 level. Therefore, the statistical hypothesis  $H_{12}$  failed to support.

In conclusion, the kinematic analysis of judo techniques has yielded significant insights into the biomechanical aspects of performance within the sport. Across various competition weight categories and selected techniques, six key kinematic variables—angular velocity, angular displacement, movement time, height of center of gravity, angle of hip flexion, and angle of knee flexion—have been examined.

The statistical results indicate that each of these variables exhibits notable differences according to competition weight categories and specific judo techniques. These findings underscore the nuanced nature of judo performance, influenced by factors such as body size, strength, skill level, and tactical approach.

From the analysis, it is evident that angular velocity plays a crucial role in technique execution, emphasizing the importance of speed and explosiveness in judo

movements. Angular displacement reflects the range of motion in joints during techniques, highlighting the need for flexibility and mobility.

Movement time signifies the temporal coordination required for effective judo performance, while the height of the center of gravity and angles of hip and knee flexion contribute to balance, stability, and biomechanical efficiency.

Overall, this study enhances the understanding of the biomechanical principles underlying judo techniques, providing valuable insights for coaches and athletes to tailor training strategies, refine technique execution, and optimize performance outcomes. By considering these kinematic variables in training and competition preparation, judo practitioners can enhance their competitive edge and achieve success in the dynamic and demanding environment of judo competition.

With this study the researcher contributes to the growing body of knowledge in judo biomechanics by revealing significant differences in kinematic variables across competition weight categories and selected techniques. By elucidating these nuances, we aim to facilitate informed coaching practices, refine training methodologies, and ultimately elevate the performance standards within the sport of judo.

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Chapter VI  
**RECOMMENDATIONS**

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Recommendations .....219

This research study was engrossed on biomechanical analysis of judo techniques, aims to provide a comprehensive understanding of the kinematic properties and its interactions involved in the execution of judo techniques. The inferences drawn out from this research could be recommended to the field of Sports Training and Coaching in judo, Sports Sciences, Sports Analytics, Physical education and Sports Research

### **Recommended to the field of Sports Training and Coaching in Judo**

1. Coaches should incorporate video analysis tools to provide visual feedback to athletes. This can help athletes understand and correct their technique based on biomechanical principles.
2. Design training programs that focus on developing specific biomechanical aspects of judo techniques. Tailor programs to address the individual needs of athletes based on biomechanical analyses.
3. Develop educational resources for coaches and athletes to disseminate biomechanical findings in a user-friendly manner. This could include videos, instructional materials, and workshops to enhance understanding and application.
4. Kinematic analysis provides coaches and athletes with actionable insights during training sessions and live competitions, enabling informed decision-making on the success.

5. Use biomechanical insights to contribute to injury surveillance efforts in judo. Identify high-risk movements and work on injury prevention strategies through targeted training and conditioning.
6. Ensure that study samples represent the diversity of judo practitioners, including different skill levels, age groups, and genders. This enhances the generalizability of biomechanical findings.
7. Coaches and athletes can use this research information to optimize biomechanical efficiency and enhance performance through targeted training interventions.

### **Recommended to the field of Sports Sciences**

8. The study Encourages collaboration between sports professionals, data scientists, sports scientists, and sports industry experts to foster cross-disciplinary innovations and holistic approaches to understanding athletic performance.
9. Explore the use of wearable technology and motion capture systems to enhance the accuracy of biomechanical measurements in real-world training environments. This can provide more ecologically valid data.
10. Explore the applications of motion analysing technology and biomechanical modelling to create detailed simulations of judo techniques, providing insights into optimal movement patterns and force application.
11. To assess the common judo injuries through the detailed kinematics of technique performance, such as joint strains and impact-related injuries, to develop strategies for injury prevention.
12. Use biomechanical analysis to refine judo techniques, making them more efficient and reducing the risk of injury for practitioners.

**Recommended to the field of Sports Analytics**

13. To use the advanced statistical modeling and machine learning algorithms to enhance player recruitment and scouting processes, identifying key performance indicators and potential talent based on multi-faceted data analysis.
14. The study Promotes education and knowledge sharing to the sports analytics community, fostering the development of new methodologies, tools, and best practices through collaboration and open dialogue.
15. Explore the integration of advanced data sources such as kinematics data and player tracking data to provide a more comprehensive analysis of athletic performance.

**Recommended to the field of Physical Education and Sports Research**

16. The study Promotes education and knowledge in judo and biomechanics, sharing within the sports analytics community, fostering the development of new research methodologies, tools, and best practices through collaboration and open dialogue.
17. Conduct biomechanical studies comparing judo techniques across different age groups and genders to understand how techniques can be adapted for different demographics.
18. Similar study can be conducted focusing on Kinetic and Anthropometric variables.
19. Similar studies can be conduct on other combat sports disciplines also.
20. Similar studies can be done on international level judo practitioners.
21. Studies could be re structured by including other kinematic variables.

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## **APPENDICES**

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## Appendix A

### Body Landmark Measurements of Judokas

Weight Category: 60 kg (Criterion- cm)

Judokas	St. Height	Si. Height	AL	UAL	FAL	LL	ULL	KNL
1	168	87	74	28	43	93	50	43
2	164	84	72	24	47	95	49	49
3	164	83	71	27	45	99	50	49
4	160	80	70	22	46	92	51	41
5	162	82	71	24	44	95	50	45
6	170	86	74	23	45	91	49	50
7	169	88	76	29	46	101	49	53
8	176	88	78	31	48	101	46	56
9	160	86	70	20	42	93	50	43
10	175	86	76	26	45	95	51	44
11	168	86	76	28	42	99	51	48
12	165	84	71	21	44	92	50	42
13	166	82	73	22	42	94	50	49
14	168	86	74	24	42	92	52	40
15	172	88	76	26	44	99	55	44

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## Body Landmark Measurements of Judokas

Weight Category: 66 kg (Criterion- cm)

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Judokas	St. Height	Si. Height	AL	UAL	FAL	LL	ULL	KNL
1	169	89	75	28	48	93	46	50
2	166	88	71	29	45	92	39	52
3	166	87	71	27	43	95	49	48
4	174	90	76	29	47	104	53	54
5	168	88	72	29	46	94	46	50
6	168	88	75	29	45	91	42	51
7	168	88	69	29	44	99	48	46
8	167	87	72	29	45	93	45	-
9	183	92	82	33	50	100	52	56
10	169	89	76	27	49	94	46	50
11	157	81	70	27	43	93	47	48
12	164	86	73	29	44	93	43	48
13	172	88	76	29	45	95	45	50
14	168	88	69	29	44	99	48	50
15	168	87	71	27	43	95	49	49

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**Body Landmark Measurements of Judokas****Weight Category: 73 kg (Criterion- cm)**

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<b>Judokas</b>	<b>St. Height</b>	<b>Si. Height</b>	<b>AL</b>	<b>UAL</b>	<b>FAL</b>	<b>LL</b>	<b>ULL</b>	<b>KNL</b>
1	168	87	78	29	46	94	46	50
2	178	88	82	30	50	101	51	52
3	169	89	76	27	49	94	46	50
4	182	87	82	32	48	106	48	65
5	184	89	84	39	49	108	50	58
6	178	90	80	32	48	100	49	51
7	181	93	80	33	46	103	53	53
8	172	84	79	30	47	99	50	51
9	160	84	72	26	44	88	49	46
10	173	89	74	26	46	100	52	52
11	170	86	73	30	44	93	43	48
12	165	86	74	29	44	95	46	50
13	172	89	78	30	49	102	48	54
14	171	88	76	29	49	104	50	55
15	170	84	76	31	45	99	52	48

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## Body Landmark Measurements of Judokas

Weight Category: 81 kg (Criterion- cm)

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Judokas	St. Height	Si. Height	AL	UAL	FAL	LL	ULL	KNL
1	178	90	80	32	48	100	49	51
2	174	90	76	29	47	104	53	54
3	183	92	82	33	50	108	52	56
4	178	94	81	32	49	102	52	50
5	173	84	79	30	47	99	51	50
6	182	93	81	31	49	106	54	53
7	170	89	76	30	44	100	52	43
8	183	92	82	33	30	108	52	56
9	180	91	78	30	48	105	47	59
10	179	91	82	33	48	106	53	53

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**Body Landmark Measurements of Judokas****Weight Category: 90 kg (Criterion- cm)**

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<b>Judokas</b>	<b>St. Height</b>	<b>Si. Height</b>	<b>AL</b>	<b>UAL</b>	<b>FAL</b>	<b>LL</b>	<b>ULL</b>	<b>KNL</b>
1	186	95	83	32	53	107	52	55
2	176	91	82	32	51	99	47	53
3	177	87	84	32	50	106	51	56
4	187	92	81	34	50	108	52	56
5	183	92	82	32	49	106	53	53
6	184	97	84	35	50	103	48	55
7	186	95	83	32	53	107	52	56
8	180	91	78	30	48	105	47	59
9	179	91	82	33	48	106	53	53
10	183	92	82	33	30	108	52	56

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## Body Landmark Measurements of Judokas

Weight Category: 100 kg (Criterion- cm)

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Judokas	St. Height	Si. Height	AL	UAL	FAL	LL	ULL	KNL
1	170	89	78	31	48	97	48	50
2	174	92	73	29	46	93	47	47
3	180	88	83	33	50	103	46	58
4	175	88	80	30	52	105	52	53
5	184	97	84	35	50	108	48	60
6	186	95	83	32	53	107	53	54
7	179	91	82	33	48	106	53	53
8	174	90	78	29	49	95	44	50
9	188	95	82	32	50	102	52	50
10	190	97	84	33	52	111	55	57

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**Body Landmark Measurements of Judokas****Weight Category: 100+ kg (Criterion- cm)**

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<b>Judokas</b>	<b>St. Height</b>	<b>Si. Height</b>	<b>AL</b>	<b>UAL</b>	<b>FAL</b>	<b>LL</b>	<b>ULL</b>	<b>KNL</b>
1	178	91	83	33	50	103	50	53
2	189	96	83	32	50	102	51	52
3	179	92	81	34	48	102	47	56
4	186	95	83	32	53	107	53	54
5	192	97	85	34	55	108	54	54
6	190	97	84	33	52	111	55	57
7	188	95	82	32	50	102	52	50
8	178	90	80	33	51	101	52	50
9	176	95	82	35	48	102	52	50
10	176	98	80	32	48	100	47	52

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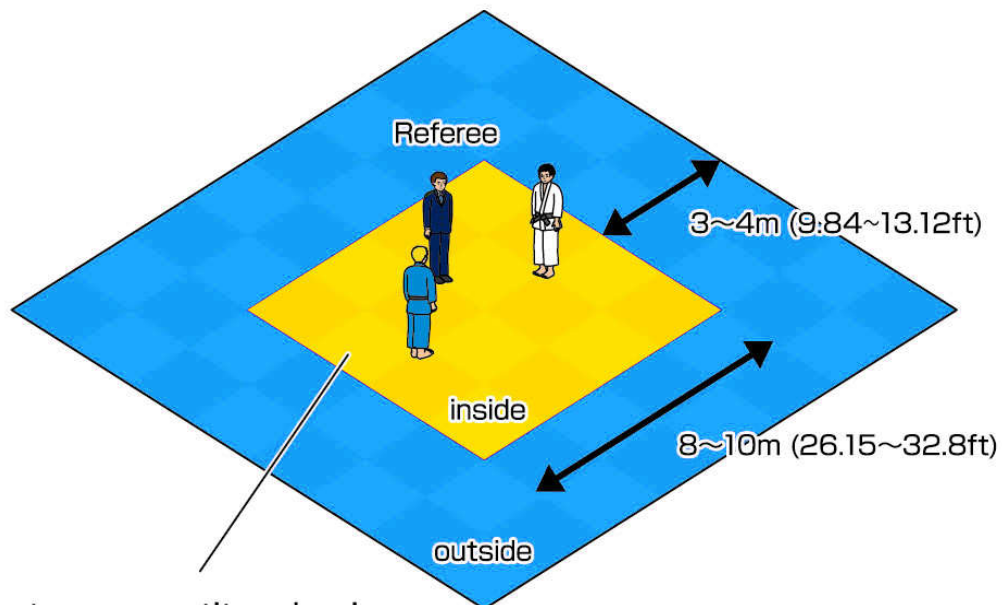
## Appendix B

### Detailing of samples

SL No.	Year	Number of Observed Bouts/ Videos
1	2017	180
2	2018	230
3	2019	220
4	2020	210
5	2022	210

## Appendix C

**A schematic diagram of the Tatami  
(Calibration)**



The two competitors begin and end the match with a bow at two lines in the center.

Source: [https://web-japan.org/kidsweb/img/virtual\\_judo02\\_pic01.jpg](https://web-japan.org/kidsweb/img/virtual_judo02_pic01.jpg)

$$x = (X - a)$$

Where  $X = 10m$

$a$  = Distance from the starting point of Kumikata for the technique to the outer edge of the tatami.