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Information Article

A Comparative Analysis of Kinematic Variables Between the Dimidov and Healy Skills: Biomechanical Implications for Routine Construction on the Parallel Bars

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ABSTRACT

The purpose of this study is to compare kinematic parameters of accomplishment of the skills Dimidov and Healy when performed on the parallel bars, and find out biomechanical aspects for using this exercise in artistic gymnastics during training sessions. The descriptive method with a comparative approach was adopted. The physical characteristics of the research sample were five advanced-level male gymnasts who were able to perform both skills. High speed cameras were used in conjunction with the Kinovea motion analysis software to extract relevant kinematic variables: shoulder, elbow and hip joint angles, linear velocity, angular velocity, angular acceleration, trajectory of body's center of mass, and movement time, among other variables, across different phases of the performance. Execution of both skills (Dimidov and Healy) was split into three stages – preparatory, main and final – in order to study the mechanics of each stage of the skills separately. Several kinematic variables in the results showed that there were significant differences between the two skills, at least statistically: angular velocity, angular acceleration, and movement time. The Dimidov skill had higher angular velocities and angular accelerations, shorter movement time and had a transitional nature, requiring higher angular momentum to be generated in a short time window. In contrast, Healy's best skill showed longer movement times and relatively low angular velocity and acceleration values, suggesting that he relies on the continuity of movement and rotation control of rotational inertia in longitudinal axis rotation. The kinematic differences between the movements in the Dimidov and Healy skills may also have important implications for the functional role of each of these skills in a parallel bars piece, and, therefore, highlight the importance of using the skills in accordance with their kinematic properties to maximize the efficiency of movement production and, consequently, technical performance.

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1- Introduction to the Research

The parallel bars apparatus is one of the basic apparatuses for the Artistic gymnastics as it needs correct use of physical force, neuromuscular coordination and control of the movement momentum during the performance. The sequence of skills for the routine performed on this apparatus is designed using a skill sequence that will be as mechanically efficient as possible, maintaining continuity and flow of the routine with the minimizing of energy loss when changing the way the apparatus is held and utilized. In the scientific basis of the analysis of motor performance, kinematic variables are among the most important since they give rise to accurate quantitative indicators which reflect the nature of the movement, both in terms of displacement and velocity, and also of angular acceleration and time. They also help in the understanding of the quality of technical execution not only for descriptive evaluation purposes. Although there are differences in the mechanics of the Dimidov and Healy skills - direction of rotation, source of torque to create angular momentum, and control of the body during the move, these are significant skills for meeting parallel bars technical difficulties and for connecting components of a parallel bars routine together. This distinction causes each Skill to have varying biomechanical demands and, therefore, this varies how the Skill should be performed, as well as the point in the routine at which it is performed. Although plenty of emphasis has been placed on the importance of these two skills, only coaches' experience can give rudimentary clues about what constitutes technical superiority and what might underlie it. This emphasizes the importance of accurate kinematic analysis as a scientific objective tool. Therefore this study's significance lies in an attempt to compare kinematic variables between the Dimidov and Healy skills, and provide an understanding of how the variables in each skill relate to biomechanics to aid in routine construction on the parallel bars, offering a scientific basis of how and why to select and sequence skills to ensure the greatest possible movement efficiency and the optimal technical performance.

Research Problem

The problem with creating routines on the parallel bars is technical and biomechanical, selecting and arranging skills to fit within a discontinue or flow pattern and then maintaining momentum when performing different skills including transition skills which require a high level of co-ordination and control of movement. The Dimidov and Healy skills are important skills on the parallel bars – each is important for linking movement on the bars and with regard to the technical difficulty requirements – although the nature of performance in each skill is different. While both of these skills are common, their appropriation in a routine is based not so much on careful scientific analysis, but on how often they've been applied and observed firsthand. Poor understanding of the nature of each type of movement in which the skill is being trained or requires to be learned, or at the wrong location in the performance area, may lead to poor training or poor selection of the skill location in the performance which can negatively impact on continuity and quality. Hence, the research problem is that there is a need for a comparative study to illuminate the kinematic variables and their biomechanical implications associated with the execution of two skills (Dimidov and Healy) and to bring this optical study closer to the body of the knowledge on processing of routine construction on the parallel bars on the basis of precise science.

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Research Objectives

This research aims to:

• Identify the values of the basic kinematic variables accompanying the performance of the Dimidov and Healy skills on the parallel bars.

• Compare the kinematic variables between the Dimidov and Healy skills to reveal similarities and differences in the characteristics of motor performance.

• Determine the differences in angular velocity, angular acceleration, and movement time between the two skills during the different performance phases.

Research Hypotheses

• There are statistically significant differences in the kinematic variables between the Dimidov and Healy skills on the parallel bars.

• There are statistically significant differences in angular velocity and angular acceleration between the Dimidov and Healy skills during the different performance phases.

• There are statistically significant differences in movement time between the Dimidov and Healy skills on the parallel bars.

Research Fields

Human Field The research included a sample of artistic gymnastics players, numbering five players, who were proficient in performing the Dimidov and Healy skills on the parallel bars.

Temporal Field The time period extended from 1/10/2024 to 1/11/2024.

Spatial Field The field experiment was conducted in the hall of the College of Physical Education and Sports Sciences, University of Baghdad.

Terms

Kinematic variables: A set of variables used to describe movement without addressing its causes. They include displacement, velocity, acceleration, angles, angular velocity, angular acceleration, and movement time, and they are extracted by analyzing the movement path of body segments or the body center of mass during skill performance.

Dimidov: A transitional rotational skill on the parallel bars that depends on converting the angular momentum generated from the backward swing into a forward transitional movement with redirection of the body around the shoulder joint to move from the hanging position to the support position.

Healy: A rotational skill on the parallel bars characterized by rotation around the longitudinal axis of the body during movement. It depends on controlling inertia and timing the rotation to achieve movement continuity and balance during performance.

Routine: A sequence of interconnected motor skills performed by the gymnast on the apparatus according to a specific system. It aims to meet the requirements of technical difficulty, flow, movement economy, and mechanical stability during performance.

Parallel bars: One of the men's artistic gymnastics apparatuses, consisting of two parallel rails, and performance on it requires a high balance among strength, control, and movement precision during the execution of different skills.

2- Research Methodology and Field Procedures

The researcher adopted the descriptive method because it suits the nature of the study, which aims to compare the kinematic variables between the Dimidov and Healy skills on the parallel bars.

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2-1 Research Sample

The research sample was intentionally selected from advanced artistic gymnastics players who had the ability to perform the Dimidov and Healy skills on the parallel bars. Five players were selected for the sample based on the fact that they had a reasonably comparable physical and skill level which enabled biomechanical analysis to be done accurately and objectively. Homogeneity was established for the sample in the basic variables represented by age, height, and weight to verify their statistical closeness, using the arithmetic mean, standard deviation, and skewness coefficient, as shown in Table (1).

Table (1) Homogeneity of the research sample in the means, standard deviations, median, and skewness coefficient for height, weight, and age

No.	Statistical parameters / Variables	Mean	Median	Standard Deviation	Skewness Coefficient
1	Height (cm)	172.6	173.0	4.05	-0.21
2	Weight (kg)	68.9	69.02	3.72	0.18
3	Age (years)	18.4	18.01	0.96	0.141

2-3 Means, Tools, and Devices Used in the Research

2-3-1 Means of Collecting Information

The researcher used a set of approved scientific means to obtain the data and information required to achieve the research objectives accurately and objectively. These means consisted of reviewing previous studies and specialized scientific sources related to the research topic, using the international information network (Internet), relying on organized scientific observation to follow skill performance, and using a special form to record data related to the variables under study.

2-3-2 Tools and Devices Used in the Research

The researcher relied on a set of scientific tools and devices necessary for filming and analysis in order to collect data and achieve the research objectives accurately and objectively. These tools and devices comprised of the following:

The parallel bars apparatus (legal) that meets the requirements of the International Gymnastics Federation (FIG), which will be used to perform the Dimidov and Healy skills and to capture the various stages of the movement in a video for biomechanical analysis.

2. High-speed cameras: two high-speed digital cameras were used at a filming rate of approximately 240 frames per second to film the skill performance of the Dimidov and Healy skills in a way that ensures accurate movement recording and analysis.
3. Tripods: tripods were used to stabilize the cameras.
4. Biomechanical analysis software: specialized motion-analysis software, Kinovea, was used to extract kinematic variables related to joint angles, linear and angular velocities, distances, and the trajectory of the body center of mass during the performance of the Dimidov and Healy skills on the parallel bars.

2-4 Tests and Measurements Used in the Research

The researcher adopted a set of scientific tests and measurements suitable for the nature and objectives of the study in order to obtain accurate data that contribute to analyzing the kinematic variables and interpreting their biomechanical implications during the performance of the Dimidov and Healy skills on the parallel bars. These tests and measurements included the following:

Anthropometric measurements: Height was measured using a graduated measuring tape, and weight was measured using an electronic medical scale, for the

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purpose of describing the research sample and establishing its homogeneity in the basic variables of age, height, and weight.

Skill performance test: The performance of the Dimidov and Healy skills was filmed for each player on the parallel bars. Each skill was performed in several attempts after appropriate warm-up, and the best attempt in terms of technical performance was selected for biomechanical analysis.

Kinematic measurements: The kinematic variables were extracted by analyzing the filmed recordings using specialized motion-analysis software. They included measuring joint angles, linear velocity, angular velocity, angular acceleration, displacement, movement time, and the trajectory of the body center of mass during the different performance phases of each skill.

2-5 Biomechanical Tests (Through Motion Analysis)

In this research, the researcher relied on biomechanical tests based on motion analysis to measure and determine the kinematic variables accompanying the performance of the Dimidov and Healy skills on the parallel bars. This was done by filming the performance using high-speed cameras and analyzing it using specialized biomechanical analysis software. The Dimidov skill is a transitional skill that depends on the backward swing and the generation of high angular momentum, followed by a change in the direction of movement from swinging to support through the shoulder joint, as the gymnast redirects the body's movement momentum while controlling the position of the trunk and arms to move from the hanging position to the support position on the rails. The Healy skill, however, is a rotary skill: the skill is a rotation that occurs around the body's length axis while on the parallel bars. Requires management of inertia and timing the trunk and shoulder turn to ensure the movement stays connected and a balance is maintained during performance. The analysis included measuring a set of kinematic variables represented by the joint angles of the shoulder, elbow, and hip, linear and angular velocity, angular acceleration, the trajectory of the body center of mass, and movement time for the different performance phases. To interpret the mechanical characteristics of performance accurately, the performance of the Dimidov and Healy skills was divided into successive movement phases: the preparatory phase that generates movement momentum, the main performance phase in which the transitional movement in Dimidov or the longitudinal rotation in Healy is executed, and the stability or final phase that aims to control the movement, maintain balance, and prepare for transition to the next skill within the routine.

Tools used:

• High-speed camera (240 fps).
• Kinovea video-analysis software.

2-6 Pilot Experiment

The pilot experiment was conducted on 1/10/2024 at ten o'clock in the morning on two artistic gymnastics players from outside the main research sample, in the hall of the College of Physical Education and Sports Sciences / University of Baghdad, which was the same hall in which the main experiment would be implemented. The experiment aimed to verify the safety of the field procedures related to filming and biomechanical analysis, as well as to analyze the performance of the Dimidov and Healy skills on the parallel bars. The experiment included checking the efficiency of the high-speed cameras in terms of image clarity, frame-rate stability, and absence of vibration during recording. It also included determining the best camera positions and

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suitable filming angles to ensure full coverage of the movement path of both skills and the possibility of measuring joint angles with high accuracy. The filmed recordings were also entered into Kinovea motion-analysis software to confirm the clarity of reference points and the accuracy of temporal synchronization between the start of performance and the start of filming.

The process of fixing markers on the players' main joints was also tested, including the shoulder, elbow, hip, knee, and ankle joints, in order to ensure the accuracy of measuring angles and velocities during the different performance phases. The experiment also included checking the devices and tools used in physical strength and motor-balance tests to ensure their readiness for use.

The results of the pilot experiment showed that the devices and tools used were functioning efficiently and that the field procedures could be applied within the specified time. They also indicated the possibility of making some simple organizational adjustments that helped improve workflow and increase the accuracy of collecting biomechanical-analysis data for the main experiment.

2-7 Main Tests

After completing the pilot experiment and addressing the technical and organizational observations that appeared during it, the researcher conducted the main experiment tests on the research sample of five advanced artistic gymnastics players on 3/10/2024 in the hall designated for the experiment at the College of Physical Education and Sports Sciences / University of Baghdad. The tests were implemented under unified field conditions in terms of execution time, devices and tools used, camera settings, flooring type, temperature, and order of test execution, in order to stabilize the experimental conditions and reduce the influence of external variables on the measurement and biomechanical-analysis results.

First Day

The tests related to the basic physical components were implemented and included:

• Anthropometric measurements
• Height
• Weight

Biomechanical analysis of the Dimidov and Healy skills on the parallel bars included the following:

Filming motor performance: The performance of the Dimidov and Healy skills was filmed using high-speed cameras and suitable filming angles to ensure that all movement phases were recorded accurately and in the required movement planes.

Dividing performance into movement phases: The performance of each of the Dimidov and Healy skills was divided into main movement phases: the preparatory phase, the main performance phase, and the stability or final phase, based on clear changes in joint positions and the trajectory of the body center of mass.

Visual identification of anatomical points: Visual anatomical points were identified and secured to the major joints of the body, namely shoulder, elbow and hip for the movement tracking and precise measurement of the joint angles during performance.

Extracting kinematic variables: The analysis included measuring joint angles, linear velocity, angular velocity, angular acceleration, displacement, the trajectory of the body center of mass, and movement time for each phase of performance.

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2-8 Statistical Methods

The researcher processed the statistical data using the Statistical Package for the Social Sciences (SPSS) in a way that suits the comparative nature of the research between the Dimidov and Healy skills.

3- Presentation, Analysis, and Discussion of Results

The results of the kinematic variables extracted from the biomechanical analysis of the performance of the Dimidov and Healy skills on the parallel bars were presented, statistically analyzed, and discussed, together with their biomechanical implications related to routine construction.

Table (2): Statistical parameters of the research variables at the significance level (alpha = 0.05)

Variable	Skill	Mean	Median	SD	Skew
Ang vel (rad/s)	Dimidov	6.82	6.80	0.41	-0.12
	Healy	5.94	5.90	0.36	0.08
Ang accel (rad/s²)	Dimidov	18.60	18.40	1.25	-0.15
	Healy	15.20	15.10	1.10	0.11
Time (s)	Dimidov	1.42	1.40	0.09	0.06
	Healy	1.78	1.80	0.11	-0.04
Shoulder angle (deg)	Dimidov	162.4	163.0	4.8	-0.10
	Healy	154.6	155.0	5.1	0.14
COM disp (m)	Dimidov	0.46	0.45	0.03	0.09
	Healy	0.39	0.40	0.04	-0.07

Table (3) Statistical differences in the kinematic variables between the Dimidov and Healy skills on the parallel bars (paired-samples t-test, n = 5) at the significance level (alpha = 0.05)

Variable	Mean Healy	Mean Dim	Mean Diff	t	Sig	d	Signif
Ang vel (rad/s)	5.94	6.82	0.88	4.21	0.013	1.88	Sig
Ang accel (rad/s²)	15.20	18.60	3.40	5.02	0.007	2.25	Sig
Time (s)	1.78	1.42	-0.36	-4.56	0.010	2.04	Sig
Shoulder angle (deg)	154.6	162.4	7.8	3.11	0.036	1.39	Sig
COM disp (m)	0.39	0.46	0.07	2.94	0.042	1.31	Sig

Table (4) Statistical parameters of the kinematic variables in the preparatory phase for the Dimidov and Healy skills on the parallel bars (n = 5) at the significance level (alpha = 0.05)

Variable	Skill	Mean	Median	SD
Ang vel (rad/s)	Dimidov	5.10	5.05	0.32
	Healy	4.62	4.60	0.28
Ang accel (rad/s²)	Dimidov	12.40	12.30	0.95
	Healy	10.85	10.80	0.88
Time (s)	Dimidov	0.48	0.47	0.04
	Healy	0.55	0.56	0.05

The preparatory phase shows a relative superiority of the Dimidov skill in generating initial momentum, namely angular velocity and angular acceleration, which prepares for a rapid transition to the main phase.

Table (5) Statistical parameters of the kinematic variables in the main performance phase for the Dimidov and Healy skills on the parallel bars (n = 5) at the significance level (alpha = 0.05)

Variable	Skill	Mean	Median	SD
Ang vel (rad/s)	Dimidov	6.82	6.80	0.41
	Healy	5.94	5.90	0.36
Ang accel (rad/s²)	Dimidov	18.60	18.40	1.25
	Healy	15.20	15.10	1.10
Shoulder angle (deg)	Dimidov	162.4	163.0	4.8
	Healy	154.6	155.0	5.1
Time (s)	Dimidov	0.62	0.61	0.05
	Healy	0.78	0.79	0.06

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This phase is the most distinctive between the two skills. Dimidov depends on higher acceleration and momentum, whereas Healy depends on rotational control and longer temporal continuity.

Table (6) Statistical parameters of the kinematic variables in the final phase for the Dimidov and Healy skills on the parallel bars (n = 5) at the significance level (alpha = 0.05)

Variable	Skill	Mean	Median	SD
Ang vel (rad/s)	Dimidov	3.20	3.18	0.27
	Healy	3.85	3.88	0.30
Ang accel (rad/s²)	Dimidov	6.40	6.35	0.70
	Healy	5.10	5.05	0.62
Time (s)	Dimidov	0.32	0.31	0.03
	Healy	0.45	0.46	0.04

The final phase shows the superiority of the Healy skill in control and balance, with less impulsive angular velocity, which explains its suitability for movement linking.

The results of the statistical tables for the kinematic variables showed clear statistically significant differences between the Dimidov and Healy skills on the parallel bars, whether performance was analyzed as a whole or divided into the three performance phases: preparatory, main, and final. This confirms that each skill has a different movement organization and different biomechanical requirements, despite belonging to the same apparatus. These differences reflect a fundamental variation in the nature of the mechanical performance of each skill, which is consistent with what Arkaev and Suchilin (2004) and Bruggemann (1994) indicated regarding the specificity of the motor structure of gymnastic skills and its connection to their function within the routine. The results of Tables (2) and (5) showed that the Dimidov skill was characterized by higher values of angular velocity and angular acceleration and lower movement time, particularly in the main phase. This indicates its reliance on a rapid transitional performance pattern that requires generating high angular momentum within a short time to achieve the movement transition from swing to support with high efficiency. This interpretation agrees with Sands (2000) and McLaughlin and Dillman (1997), who indicated that transitional skills on the parallel bars rely largely on maximizing angular velocity to maintain movement momentum and ensure a successful transition without loss of balance. Angular velocity is one of the most prominent kinematic variables that explained the differences between the two skills. Tables (1), (2), and (4) showed clear superiority of the Dimidov skill in angular-velocity values during the preparatory and main performance phases compared with the Healy skill, with the highest values reached in the main phase while maintaining joint control, especially at the shoulder joint. This is consistent with Hiley and Yeadon (2003) and Takei (1998) regarding the decisive role of angular momentum in successful performance on the parallel bars. The results of Table (4) also show that the higher angular velocity in the Dimidov skill was associated with lower movement time, reflecting performance efficiency and rapid transition between movement positions. In contrast, Tables (2), (3), and (6) showed that the Healy skill recorded relatively lower angular velocity and angular acceleration values with longer movement time. This reflects its nature as a rotational skill that depends on movement continuity and control of inertia during rotation around the longitudinal axis of the body. This pattern agrees with Yeadon (1993) and Winter (2009), who indicated that rotational skills require precise organization of angular velocity and movement timing more than reliance on high speed. Tables (3) and (6) also showed that the distribution of angular velocity in

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the Healy skill was more gradual during the final phase, which allows balance and movement continuity to be maintained, an essential condition for successful performance within the routine, as indicated by Hamill and Knutzen (2015). In the final phase, Tables (3) and (6) showed a clear decrease in angular velocity in the Dimidov skill. This is explained by the need to absorb momentum, achieve stability, and prepare to move to a subsequent skill within the routine. Meanwhile, the Healy skill retained relatively higher angular-velocity values to ensure continued rotation and control of movement until the end of performance, reflecting the different movement strategy of each skill, as indicated by Knudson (2007). From a biomechanical perspective related to routine construction, these results, as shown collectively in Tables (1-6), indicate that the Dimidov skill depends on a movement strategy based on generating speed and momentum in specific phases and then reducing them quickly to achieve stability, making it more suitable for transitional positions within the routine. The Healy skill, in contrast, depends on a more balanced distribution of angular velocity to ensure continuity and balance, making it more suitable for movement linking between skills. This interpretation agrees with the technical performance requirements stated in the Code of Points of the International Gymnastics Federation (FIG, 2022), and at the same time confirms what Irwin et al. (2013) indicated regarding the importance of employing the biomechanical characteristics of skills when planning routines and evaluating technical performance on precise scientific foundations, in a way that contributes to improving performance efficiency and reducing the possibility of technical error. The strength of the differences may be attributed to the homogeneity of the sample members and the closeness of their skill level.

4- Conclusions and Recommendations

4-1 Conclusions

• The results indicated that the kinematic variables differed significantly between the two skills used (the Dimidov and the Healy skills), in thus confirming the finding that the two skills are different in terms of the mechanical characteristics and the organization of the movement despite being apparently similar in the routine on the parallel bars.

• The Dimidov skill demonstrated greater values of angular velocity, angular acceleration and shorter movement time, particularly in the main phase, reflecting their emphasis on rapid high angular momentum production to efficiently achieve the movement transition.

• Healy skill demonstrated relatively lower values of angular velocity and angular acceleration and longer amount of movement time which has a rotational nature, requires regulation of inertia, continuity of movement
and balance in movement.

• Analysis of the performance phases (preparatory-main-final) shows that the main phase represents the phase with the highest mechanical-performance requirements; however, the nature of these requirements differs between a transitional skill that depends on speed, such as Dimidov, and an organizational skill that depends on control, such as Healy.

• The results showed that angular velocity is a very important kinematic variable in distinguishing between the Dimidov and Healy skills because of its direct effect on generating momentum and organizing movement within the routine.

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4-2 Recommendations

• Kinematic variables, especially angular velocity, angular acceleration, and movement time, should be adopted as basic scientific indicators when planning and constructing routines on the parallel bars.

• The Dimidov skill should be used in transitional positions within the routine that require generating high angular momentum and rapid transition between movement phases.

• The characteristics of each performance phase (preparatory-main-final) should be considered when training the two skills, with emphasis on developing angular-velocity requirements in Dimidov and movement-control requirements in Healy.

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