مخبر العلوم والخبرة وتكنولوجية النشاط البدني والرياضي/المجلد:07 /العدد:02 -.2026،
ISSN: 2716-9316
ASJP: https://www.asjp.cerist.dz/en/PresentationRevue/750

Analysis of the giant back circle on the parallel bars in men's artistic gymnastics

التحليل الحركي للدورة الخلفية الكبرى على جهاز المتوازي في الجمباز الفني للرجال

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تاريخ الإرسال: 2026-06-05	تاريخ القبول2026-06-12	تاريخ النشر: 2026-07-10-

الملخص:

هدفت هذه الدراسة إلى التعرف على تغيرات الطاقة الميكانيكية للجسم ككل والكشف عن طبيعة العمل العضلي أثناء أداء مهارة الدورة الخلفية الكبرى على جهاز المتوازي **.شملت عينة الدراسة ثلاثة لاعبي جمباز من النخبة العالمية المشاركين في كأس العالم لسنة 2019، منهم لاعبان من الدول العربية ولاعب من تركيا. اعتمدت الدراسة على تسجيلات فيديو مقدمة من الاتحاد الدولي للجمباز(FIG) ، صُوّرت في المستوى السهمي بمعدل 25 صورة في الثانية، مع استخدام مقياس مكاني للمعايرة. وتم إجراء التحليل البيوميكانيكي باستخدام برنامج** SkillSpector**ثنائي الأبعاد. أظهرت النتائج حدوث فقدان في الطاقة الميكانيكية الكلية للجسم أثناء الأداء نتيجة الاحتكاك بين يدي اللاعب وعارضتي جهاز المتوازي، إضافة إلى مقاومة الهواء. ولإنجاز هذه المهارة بكفاءة، يتعين على اللاعب إنتاج قوة عضلية كافية للتغلب على تأثيرات الجاذبية وتعويض الطاقة المفقودة. وعليه، فإن التغير في الطاقة الميكانيكية الكلية لمنظومة اللاعب والبيئة يرتبط بمقدار العمل العضلي المنجز وحجم الطاقة المبددة بفعل القوى المقاومة الخارجية.**

الكلمات المفتاحية:الطاقة الميكانيكية؛ الدورة الخلفية الكبرى؛ جهاز المتوازي؛ التحليل البيوميكانيكي؛ برنامجSkillSpector؛ الجمباز.

Abstract

This studyaimed to investigate the variation of mechanicalenergythroughout the entire body and to identify muscle action during the performance of a **giantbackwardcircle** on the parallel bars. The sampleconsisted of threeelitegymnastsrankedamong the best performers at the 2019 World Cup, includingtwoathletesfrom the Arabregion and one fromTurkey. Videorecordingsprovided by the International GymnasticsFederation (FIG) wereused for the analysis. The recordingswerecaptured in the sagittal plane ata frame rate of 25 frames per second and calibratedusing a spatial scale. Biomechanicalanalysiswasconductedusing the two-dimensional motion analysis software **SkillSpector**. The resultsindicated a loss of total mechanicalenergyduring the movement due to friction between the gymnast's hands and the parallel bars, as well as air resistance. To successfullyperform the skill, the gymnast must generatesufficientmuscular force to overcomegravitationaleffects and compensate for the lostenergy. Consequently, changes in the total mechanicalenergy of the gymnast–environment system are directlyrelated to the amount of muscularworkperformed and the energydissipatedthroughexternalresistive forces.

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Keywords: Mechanicalenergy; Giantbackwardcircle; Parallel bars; Biomechanicalanalysis; SkillSpector; Gymnastics.

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Introduction and research problem

The back giant swing (kenmotsu) in men's artistic gymnastics is recognized as one of the basic circular movements, and the execution of this requirement on the parallel bars is classified as a complex motor skill. The ability to successfully execute this complex motor skills will demand that the gymnast adjust and control his body relative to the required angular momentum (rotating about a fixed point) during each phase of the movement as he performs a complete body rotation, while maintaining body alignment in the process (Mannaa et al., 2021). Male gymnasts typically perform their multi-directional back circles in the horizontal plane whereas typically female gymnasts perform them in the vertical plane because both apparatuses are different in their construction and the timing of each athlete's entry into their respective event. In recent years, the back giant swing has become increasingly difficult due to the addition of flight elements to it; thus, the difficulties create opportunities for bonus points and value added through kinematic chains. In addition, gymnastics has progressed tremendously and there are now more skills being performed on all of the six apparatuses than ever before and there will continue to be more in the future. The majority of skills are also completed on the different apparatuses individually, but a small amount of them can be categorized into a group of skills. Skills can generalize into two categories, weighted/balance/fall or power/landing, and each category can be further divided into subcategories. All gymnastics skills will also have 4 general characteristics; core, major circle, flipping, and handstand.

A secondary skills are those that connect base level skills in the kinematic chain, including runoff, hand jumps (known as hops) and various jumps.

The purpose of this research is to develop an optimal biomechanics profile for executing a full posterior chain exercise using the parallel apparatus. There are multiple pieces of critical information necessary for evaluating the functioning of the parallel major posterior circle to ascertain if there is an excessive amount of knee torque and force generated during the exercise. Such critical information includes determining the amount and direction of the forces applied to flex the lower limb compared to the amount and type of extensor forces exerted through the shoulder joint, assuming complete postural alignment. Ultimately, the goal of all studies of this type is to identify the biomechanical components that are instrumental in providing the correct amount of torque and force needed to achieve the desired result.

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Biomechanical research on the significant exercises of the posterior chain conducted by the largest biomechanical technology firm in the world (General Electric) does not exist. Also non-existent are biomechanical studies of particular exercise circuits or components that represent one form of foundational athletic skills for executing many of those higher-skilled movements discussed; therefore biomechanically testing these movements also allows for the updating of the most current and effective techniques of instruction and coaching to improve the technique for performing these movements in all effective athletic training programmes.

The loss of energy during the performance of a Large Posterior Circle by a gymnast on Parallel Bars is caused by the friction between the gymnast's hands and the Parallel Bars as well as the resistance from moving air surrounding the gymnast. In order for the gymnast to perform this entire routine, he must also provide enough muscular force to overcome the energy loss from both friction and air resistance. The amount of total mechanical energy produced will be directly related to the amount of energy lost from both friction and air resistance as compared to the amount of muscular work done to complete the entire motion. Thus, it is critical that the mechanical energy transformation of the entire body when completing the motion of a Large Posterior Circle on Parallel Bars is analysed when deciding on the best way to assess this action. Many studies have been conducted looking at aspects of human locomotion such as walking and running; however, there are currently no studies available on the change in mechanical energy of the entire body due to the execution of large posterior cycles performed on parallel bars....

The purpose of the study

The purpose of this study is to demonstrate the changes in mechanical energy throughout the entire body, and to determine the muscular action the gymnast does during the major posterior circle on the parallel apparatus.

Search procedures

the sample

Research Analysts have utilized a comparative analysis methodology to determine how Ahmed Onder of Turkey has performed over previous seasons and achieved medals as a gymnast. Ahmed Onder recently earned a Silver medal in Parallel Bars at the 2019 World Gymnastic Championships held in Stuttgart, Germany. They have also analyzed the competitive records of Egyptian gymnast Mohamed Afifi, who won a Gold medal in Parallel Bars at the 2018 African Gymnastic Championships held in Namibia, and Algerian gymnast HilalMettaji,

who won a Gold medal in the Women's Team Event and had an impressive performance in Parallel Bars in 2019 during the African Games held in Morocco. Therefore, the researchers utilized a sample of these three athletes to compare performances as determined from their respective scores during competitions using a common scoring system (10 total score) for the purpose of analysis. The demographics (i.e., mean + or - SD) of the research sample were: age (22.7 + or - 3.7 years); weight (61 + or 2.9 kg), height (1.7 + or - 0.2 m)..

Data processing

The video is considered appropriate for the biomechanical analysis due to the design of the camera that captured this clip from the 2019 World Championships of Gymnastics in Stuttgart, Germany, at a rate of 25 frames per second, and was positioned vertically at the vacuum level within the respective event venue .

A two-dimensional kinetic analysis of the technical execution of the major skill at the back of the court was completed on January 11, 2019. The body parts associated with the performance developed using Skill Spector were analysed at 10 different points in time for the 10 different versions of the technical execution of the major back-end skill at the back of the court.

The parameters examined in this analysis were: time, angle of shoulder, hip, knee, gravitational, kinetic, rotational, and total energy. The analysis started from a handstand position and one course was divided into Four phases every 90 degrees of the angular displacement of the center of body mass. Figure (1)

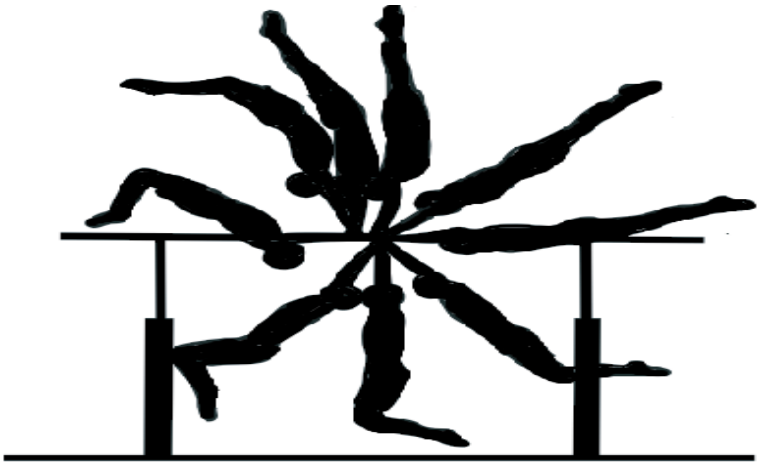


Figure (1) Study skill

There are eight distinct segments or portions of the human body providing a mathematical framework by which you can use mechanical measurements to

quantify each body section. Each segment or part (or the endpoints) has a number of characteristics that can be used as inputs to produce a comprehensive mathematical representation of the human body as a whole. These include: foot, leg, thigh, trunk, upper arm, forearm, hand, and head.

The gymnast's image angle equations allow dummies or constraints to be removed from the image's location at an Olympic-level event by creating an independent image angle that can be compared to others based on the gymnast's constraints and are designed to solve problems associated with the accuracy of the 2D DLT (direct linear transformation) technique based upon changing image angles during photo shooting (Brewin, 2003; Kwon, 2200). Once complete, the data from the initial analysis was filtered and exported to Microsoft Excel for chart creation purposes. Bacillus is the kinetic sequence of each player's major rear-moving skill using (Skill Spector) software to analyze their motor path through their joints and centre of gravity. The Bacillus was developed using (Skill Spector) software and was structured as per the associated motor sequence..(Dartfish 5.5).

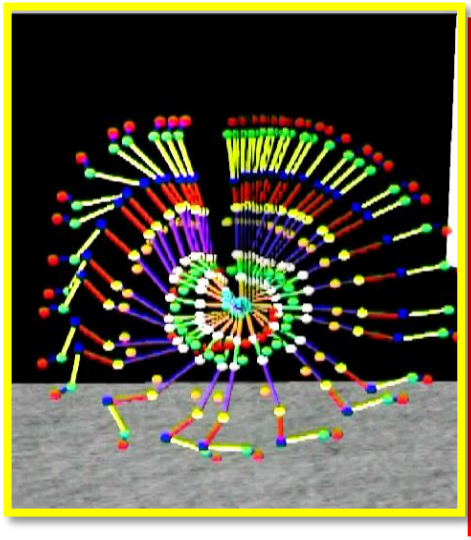


Figure (2): the first player

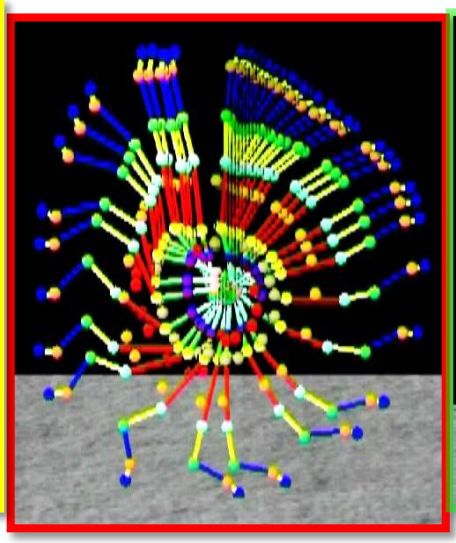


Figure (3): the second player

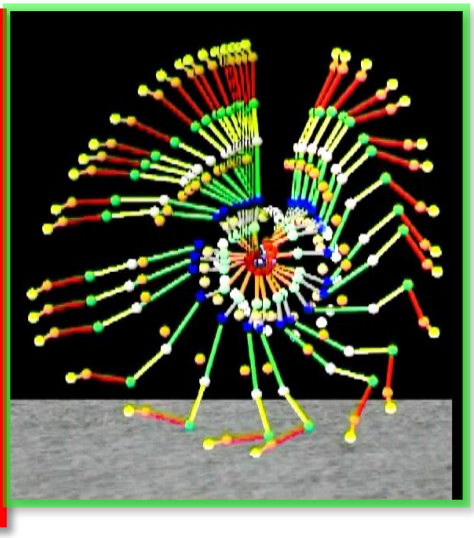


Figure (4): the third player

Results and discussions:

Table (1) the temporal composition of the technical stages of the major posterior circuit skill on a parallel apparatus.

sample	first stage	second stage	third stage	fourth stage
The first player	178.35	175.62	105.91	178.35
The second player	177.10	177.82	137.17	173.26
The third player	151.71	155.37	103.86	168.29

Gymnasts spend a lot of time on both ends of the apparatus. Gymnasts should use their angular momentum when they are moving downward and then release their angular momentum when the gymnast goes upward in a clockwise motion with respect to the weight of their body. This results in a gymnast generating clockwise momentum while moving downward and then subsequently releasing that momentum to move upward. The gymnast will experience positive angular ranges of motion at the shoulder, hip, and knee due to the design of the paralell bars and the limiting factors of the apparatus in regards to height, the direction of the apparatus, and the way that the gymnast grabs onto an object. Therefore, the energy of the body and the motion of the gymnast together create what I am discussing.

According to Burton et al. (2023), Irwin (2022) and Sayah (2025), the quality of the giant circle is influenced by how efficiently mechanical energy is transferred between the apparatus and the body of the gymnast.

Table (2) shoulder angle data

sample	first stage	second stage	third stage	fourth stage
The first player	178.35	175.62	105.91	178.35
The second player	177.10	177.82	137.17	173.26
The third player	151.71	155.37	103.86	168.29

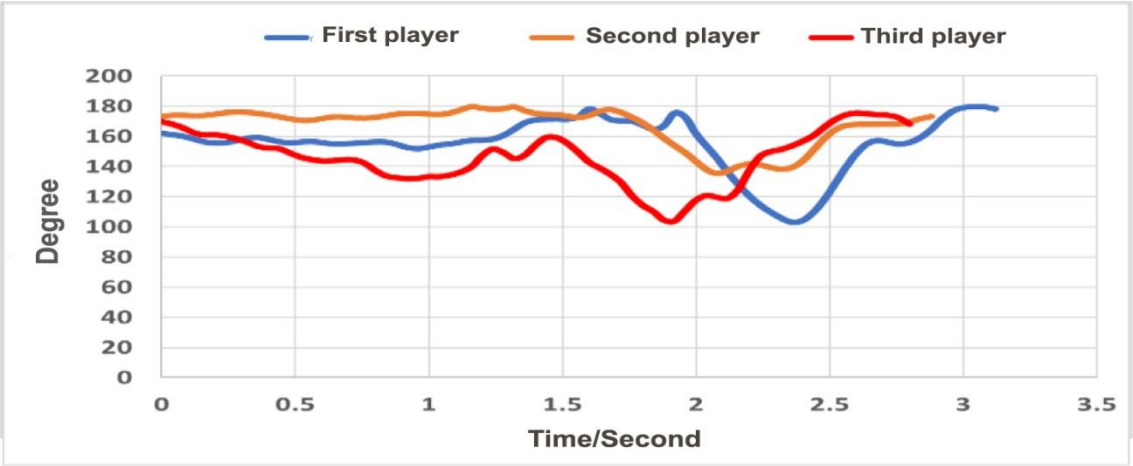


Figure (5) the shoulder angle of the research sample

Table (3) hip data for the research sample

sample	first stage	second stage	third stage	fourth stage
The first player	162.52	171.34	149.05	168.31
The second player	163.40	166.89	142.08	168.31
The third player	178.0233	170.7483	154.6982	170.7149

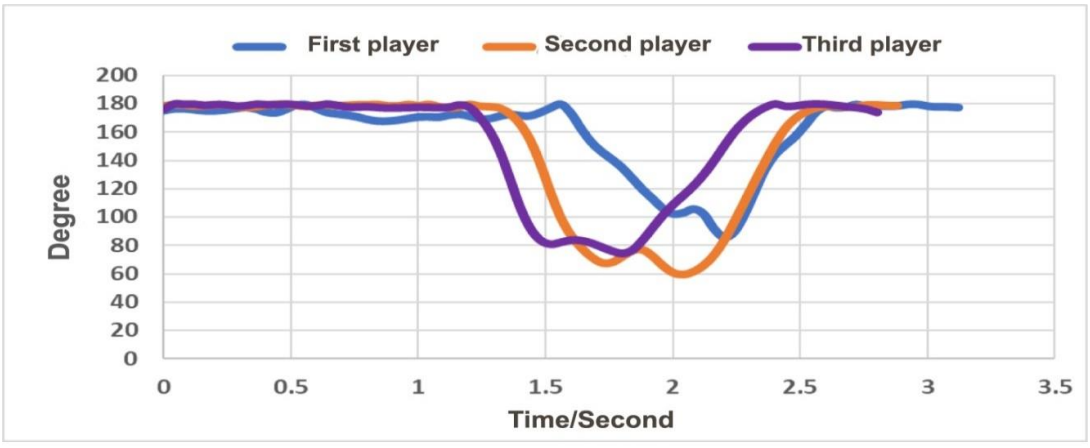


Figure (6) the hip angle diagram and the research sample

Table (4) Knee data for the research sample

sample	first stage	second stage	third stage	fourth stage
The first player	50.76	-568.89	125.12	503.29
The second player	55.73	-577.70	161.95	538.03
The third player	56.4	-627.87	122.83	537.74

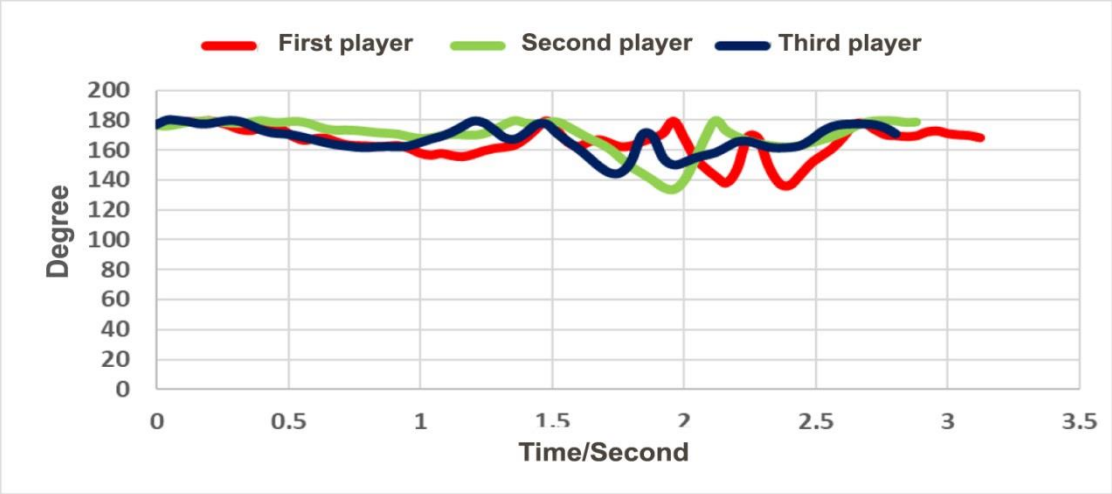


Figure (7) knee angle of the research sample

Tables 2, 3 and 4 and Figures 5, 6 and 7 demonstrate the change in the shoulder and hip angles as the shoulder joint expands in phase 3 and begins to flatten in the first half of phase 4. As the hip joint was flexed slightly during the last half of phase 2, it also continued to be flexed forward during the majority of phase 3; however, it increased significantly at the end of phase 4.

According to Tsuchiya et al. (2004), during parallel bars, the shoulder joint angle is smaller than the wise bar by a comparable proportion, while the hip joint angles for both pieces of equipment appear to be identical; however, the extension and upward flexion of the hip require greater resistance to reverse movement on the parallel than the cut on the wise. As there is also a maximum height of 180" from floor to the apparatus for both types of devices, to achieve the upward motion required for all exercises, the gymnast must provide vertical forces. Knees bent in a hang position on the apparatus at height 260' can reach more than a total extent of knee flexion if the height of their apparatus is the highest they will ever be able to keep their knees straight. All-around apparatus

at 230 inches above the floor will allow gymnasts to execute all movements possible through the leg in a single vertical plane from the floor without regard to how the motion will be directed to create an overall normal vertical axis through any given body part within that movement. Generally, the ascent velocity (the angular velocity of the leg during descent) is decreased while the ascent velocity of the leg is increased, which means that the amount of time that can be spent in the bent-knee position can be used to reduce the inertia of the entire swing (so long as the knee remains bent) because of the reduced inertia of all other body parts.

Table (5) Gravitational Energy Data for the Research Sample

sample	first stage	second stage	third stage	fourth stage
The first player	343381	1536035	339040	926
The second player	688645	1536035	484795	6778
The third player	550445	1953958	452389	6778

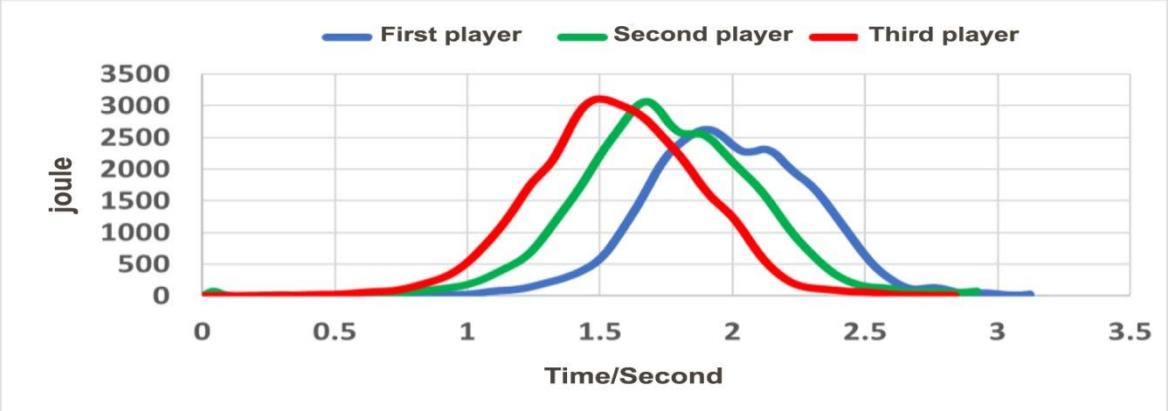


Figure (8) graph of gravitational energy and the research sample

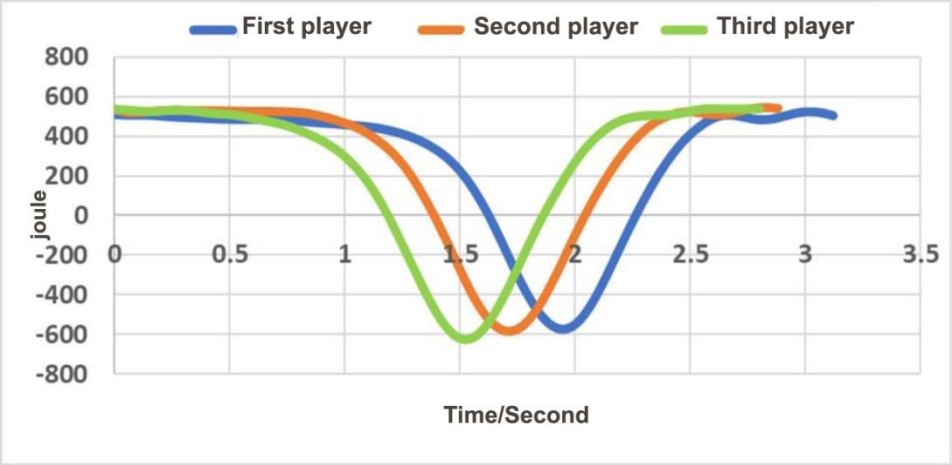


Figure (9) graph of kinetic energy and the research sample

Table (7) the rotational energy data for the research sample

sample	first stage	second stage	third stage	fourth stage
The first player	1716.67	2613.09	1630.13	28.91
The second player	1823.22	3064.44	1588.47	75.71
The third player	1770.75	3096.55	1630.13	9.51

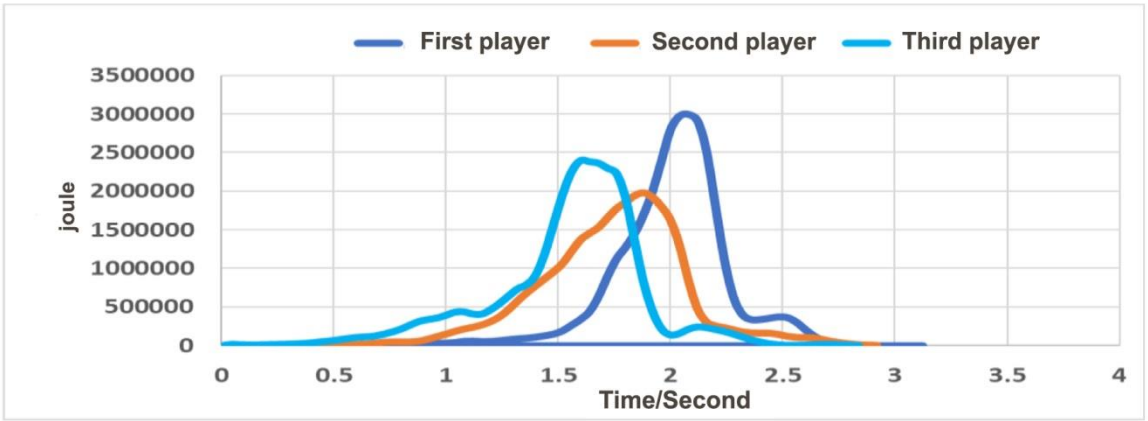
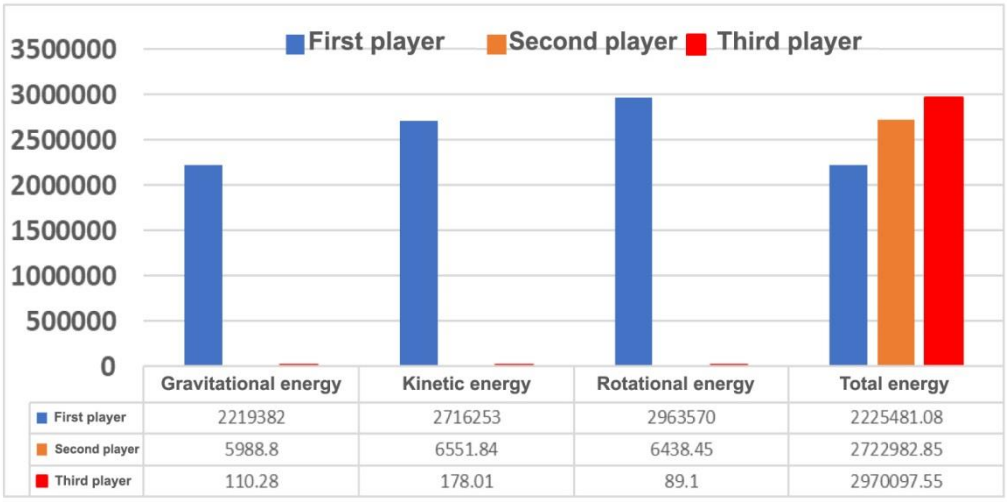


Figure (10) graph of rotational energy and the research sample

Looking at table (5)-(7) and figure (8)(9)(10) for Phase 1 data shows that players have gravitationally gained energy in Phase 1. The amount of gravitational energy gained was lost in Phase 2 and then gravitational energy in Phase 3 and Phase 4 increased again. The total energy of rotation gained during

this study, rotational energy in both Phases 1 and 2, and therefore the first two sections accumulated rotational energy; (2) lost rotational energy throughout Phases 3 and 4. The rapid increase of total internal kinetic energy during Phase 2 and the time it takes to reach the fastest rate of increase for internal and rotational energy occurs in the second half of Phase 2, whenever the maximum internal kinetic energy reaches its highest level occurs during the first half of Phase 3, and thereafter, the maximum internal kinetic energy continues to decline in each phase.Although some energy changed from potential to kinetic (and some to rotational) when it became kinetic/rotational, there were still some potential energies that were not converted into kinetic motion due to the various types of friction that existed between each hand and its beam (the outer beam) and because of friction from air as the object passed through the air (the object).



	Gravitational energy	Kinetic energy	Rotational energy	Total energy
First player	2219382	2716253	2963570	2225481.08
Second player	5988.8	6551.84	6438.45	2722982.85
Third player	110.28	178.01	89.1	2970097.55

Figure (11): graph of total energy and the research sample

From the diagram in Figure 11, we can see that rotational energy is larger than both potential and kinetic energies, and kinetic energy is therefore the largest gravitational energy of the players. Although the third player had the greatest total energy of all players, player two had the next highest total energy; and player one had the least total energy due to the player's center of mass being on the axis of rotation of an extended shoulder joint with further flexion of the hip and knee creating a decreased torque of inertia and therefore an increase in angular momentum due to the superior rotational energy of the third player over all other players..

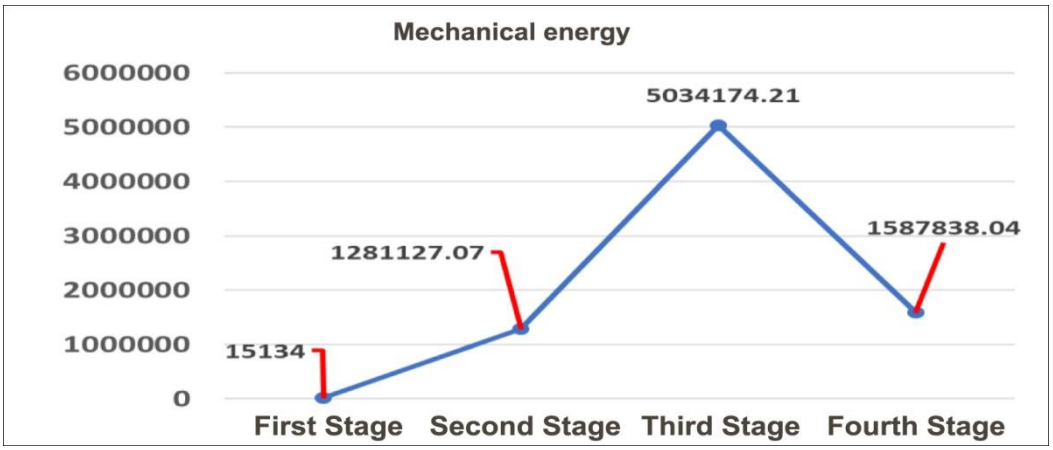


Figure (12) graph of the total energy and the research sample during the stages

The graph in figure 12 shows how much potential energy has been converted to both kinetic and rotational forms. However, not all of the potential energy is converted into kinetic shape because a certain amount of the potential energy was lost through friction between the person's hand and the parallel beam and air resistance. There was also some amount of elastic energy that did not convert to mechanical energy (kinetic and/or potential) due to friction between the hand and the parallel beam. Most elastic energy (from parallel beam) and some elastic energy (from parallel beam) was converted back to potential energy at stages 3 and 4. Stage 3 restored nearly all of the energy (potential and or kinetic) that was used during stage 1 and stage 2. The gymnast's muscular effort resulted in an increase in mechanical energy as well as converting elastic potential energy from the parallel beam to mechanical energy to lift the gymnast's body. Additionally, due to changes at each corner of the joint and in total energy, it appears that the muscular effort was applied from shoulder extension and hip and knee flexion during the third stage of the movement.

The conclusion:

1. In both stages, the overall mechanical energy decreased for the entire body in the second half, and the mechanical energy loss was due to friction between the hand on the opposing device and the atmosphere's friction onto the parallel device.

2. In stage three, the total mechanical energy from the whole body was returned. These findings indicate that muscular effort was used to recover this energy in the first half of the lift (by bending the hip and extending the shoulder). There were also decreases in muscular effort toward the end of the lift as well as there being constraints on the amount of height that could be achieved with the equipment.

3. The greater circle acceleration increased due to the reduction of the inertia torque by bending the knee joint for the purpose of completing rotation.

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