THE INVESTIGATION OF APPROACH RUN IN TERMS OF AGE, GENDER, BIO-MOTOR AND TECHNICAL COMPONENTS ON VAULTING TABLE

Işık Bayraktar[1], Berfin Serdil Örs[2], Emre Bağcı[3], Mustafa Altunsoy[3], H. Ahmet Pekel[3]

[1] Department of Coaching Education, Faculty of Sport Sciences, Alanya Alaaddin Keykubat University, Alanya, Turkey
[2] Department of Coaching Education, Faculty of Sport Sciences, Aydin Adnan Menderes University, Aydin, Turkey
[3]Department of Coaching Education, Faculty of Sport Sciences, Gazi University, Ankara, Turkey

Original article, DOI:10.52165/sgj.13.2.275-285

Abstract

Vault is one of the main apparatuses for both female and male gymnasts in artistic gymnastics (AG). The optimal vaulting technique depends on many variables, such as the approaching run. Gymnastics is one of the early specialization sports as it is necessary to start training at an early age. For this reason, the aim of the current study was to investigate the relationship among age, biomotor and technical components in relation to the approach run velocity and other variables in AG. Furthermore, similarities and differences between genders were researched. Twenty female and twelve male gymnasts took part in the study. Speed, agility, explosive power, run-up velocity were measured. Additionally, Reactive Strength Index (RSI) and Peak High Velocity distances (PHV_Distance) were calculated. Kinematic parameters during the handspring vault were calculated by a two-dimensional video analysis. A statistical comparison between genders was performed by the Mann Whitney U test. The relationships between parameters were given by Spearman correlation coefficients (r). Anaerobic power, 0-20 m speed, 20 m speed velocity, and the hand contact time were significantly different between genders (p<0.05). The approach run significantly correlated with the chronological age (r=0.66; p=0.002 for female and r=0.96; p<0.001 for male gymnasts), PHV_Distance (r=0.69; p=0.001 for female and r=0.97; p<0.001 for male gymnasts) and the biological age (r=0.69; p=0.001 for female and r=0.97; p<0.001 for male gymnasts). As the approach run velocity increases, vaulting performance is affected positively. While speed tests significantly correlated with the approach run in male gymnasts, there was no correleation for females. In addition, trainers should keep in mind that the relationship between bio-motor development and biological age of gymnasts is important in training programs.

Keywords: *vaulting table, peak high velocity distance, maturity level, kinematic analysis.*

INTRODUCTION

Unlike most other sports, which usually consist of a few activities or apparatuses, artistic gymnastics (AG) includes multiple competition performances on different apparatuses. The vaulting table is one of the main apparatuses for both female and male gymnasts. Gymnasts may perform several vaults chosen from the Code of Points (CoP) which determines the difficulty level. Handspring is considered as a fundamental vault element for gymnasts due to its developmental role in the acquisition of more complex vaults (Irwin & Kerwin, 2009). Each element performed on the vault table comprises seven distinctive phases: running, jumping on the take-off board, take-off board support, the first flight phase, table support, the second flight phase, and landing (Čuk and Karacsony, 2004; Atiković & Smajlović, 2009; Atiković, 2012; Prassas et al., 2006; Takei, 2007). The optimal vaulting technique depends on many variables (Eb et al., 2012). Three biomechanical variables are suggested to be predictors of a successful vault run: (1) degrees of turns around the transversal axis, (2) degrees of turns around the longitudinal axis, and (3) body's moment of inertia around the transversal axis in the second flight phase (Atiković & Smajlović, 2011). Furthermore, successful performance requires optimisation of all seven phases (Elizabeth et al., 2010). Among these phases, the vault run is considered to be the basis of the kinetic energy production (Atiković, 2012; Naundorf et al., 2008) and the approach-run is crucial to achieve task dependent velocity before the vaulting motion (Haigis & Schlegel, 2020). Small velocity decreases at the approach run stage may be necessary for visual adjustments in the final steps to land onto the take-off board (Bradshaw, 2004). Gymnasts usually reach the maximum run-up speed a couple of meters before the final foot contact, before they hit the take-off board (Čuk and Karacsony, 2004; Eb et al., 2012). The ability to take off is critical to perform vault elements (Bradshaw & Rossignol, 2004).

Gymnastics is categorized as one of the early specialisation sports branches. It requires many skills, such as coordination and a developed central nervous system. In order to succeed in sports like gymnastics, it is necessary to start training at an early age (Temürçi et al., 2020). As training starts at an early age, the explosive power of gymnasts may be influenced by specific training (Bencke et al., 2002). It is critical for gymnasts (Salam & Jaafar, 2020) to have adequate explosive power to implement movements while maintaining body control. Long-term athlete development (LTAD) is an approach to sport that describes a model that starts in childhood and follows a planned, systematic, and person-centred path (Balyi et al., 2013). On the other hand, biological maturity is determined using the skeletal age, gender development status and somatic maturity (Malina and Bouchard, 1992). In LTAD, athletes' personal characteristics such as age, physical and mental maturity are considered (Temürçi et al., 2020).

Biomechanical characteristics of a movement, affected by bio-motor development, is a factor that decides the difficulty of an element in gymnastics. In addition, jumping performance and running speed are reported to be predictors of the vaulting ability in gymnastics (Fernandes et al., 2016). The running approach in vaulting is carefully measured and rehearsed by gymnasts to ensure reliable performance. However, some problems such as balking, finding the run-up uncomfortable, or landing on the back of the take-off board contribute to sub-optimal vaulting performance. Due to our limited knowledge on this topic, these incidences of poor vault running may be frustrating for both the gymnasts and their coaches (Bradshaw, 2004). For this reason, the aim of the current study was to investigate the relationship between age, bio-motor development and the approach run. Gender differences were also investigated.

METHODS

Twenty female and twelve male national team gymnasts participated in this study; the descriptive data of gymnasts is given in Table 1.

All gymnasts performed the handspring element in a gymnastics hall. Before the tests, gymnasts completed a standardised warm-up for approximately 15 minutes (Mkaouer et al., 2018) including jogging, different jumps, stretching and preparations for the handspring vault. The vaulting table was adjusted to a height of 1.25m for female gymnasts (FIG, 2016a) and 1.35m for male gymnasts (FIG, 2016b). Participants did not receive any verbal encouragements during the experimental sessions. Before the experimental session started, gymnasts were given standardised instructions explaining the tests and they were familiarised with the experimental sessions.

Calculation of Peak High Velocity Distances. Gymnasts' chronological ages were recorded and Peak High Velocity (PHV) distances for each gymnast were calculated according to the following equations (Mirwald et al., 2002):

For men: Maturity Offset = –9.236 + [0.0002708 × (leg length x sitting height)] + [–0.001663 × (age x leg length)] + [0.007216 × (age x sitting height)] + [0.02292 × (body weight/height)]

For women: Maturity Offset = –9.376 + [0.0001882 x (leg length x sitting height)] + [0.0022 x (age x leg length)] + [0.005841x (age x sitting height)] + [—0.002658 x (age x body weight)] + [0.07693 x (body weight/height)]

Speed measurements. To determine gymnasts' speed, photoelectrical timing gates (FusionSport, Australia) were used. Gymnasts were asked to stay behind the first timing gate and be ready to sprint. When they broke the beam of the first gate, the timing started. The test was completed when the gymnast ran through the second gate which was 20m away from the first gate (Örs et al., 2017).

Pro Agility Test (ProAg-T). A timing gate at the starting line (Fusionsport, Australia) was placed for the ProAg-T test. On the left and right side, pins were positioned 5 yards apart (4,57m). When set, each gymnast initially touched the right pin followed by the left pin and finished the test by passing the starting line. The completion time for each gymnast was recorded (Daves and Roozen, 2012).

Run-up velocity measurements. The approach velocity leads to the performance of more difficult vaults and approach runs typically maximise it (Bradshaw, 2004). Furthermore, the running velocity is expected to increase with a certain rhythm. Especially the velocity of the athlete in the last 10meters is considered to be the most important indicator of performance (Bayraktar & Çilli, 2018). For this reason, the last 10 meters were divided into two parts to examine whether there was a change in speed in the last phases of the run, compared to the whole 10 meters:

(1) 13-8 meters (V_1),
(2) 8-3 meters (V_2),
(3) 13-3 meters (V_{10}).

The photocells (SmartSpeed, FusionSport, Australia) were placed to the last 10 meters of the vault run-up to the mat to measure the run-up velocity (Figure 1). The photocells used to determine the running times of gymnasts were placed at 3m, 8m, and 13m in front of the vaulting table (perpendicular). The photocell at 13m away from the vaulting table triggered the chronometer, the one at 3m away stopped it. The photocell at 8m recorded the split time. The following equations were used to calculate the velocity of the last 10m approach run separately for 5m and 10m.

$$Velocity\ (V) = Distance\ /\ Time$$
$$Velocity\ (V) = 5m\ /\ Time$$
$$Velocity\ (V) = 10m\ /\ Time$$

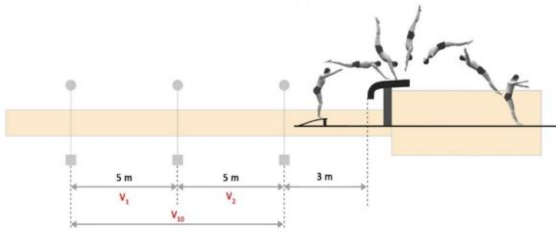

Figure 1. Photocell Placement.

Countermovement Jump (CMJ). To calculate the countermovement jump (CMJ) height, an electronic timing gate and a Smartjump mat were used (SmartSpeed, FusionSport, Australia). Gymnasts performed three maximal CMJ (Marques et al., 2009). From a standing position, gymnasts performed the crouching action (knees in full extension) and an immediate jump to reach the maximum height. Any influence of arm swings was eliminated by keeping hands on the hips (Vescovi & McGuigan, 2008). All gymnasts performed three repetitions and the best one was recorded.

Drop Jump (DJ). Gymnasts performed three maximal jumps on the electronic Smartjump mat (SmartSpeed, FusionSport, Australia) at 40cm DJ height. Gymnasts were instructed to step out of the box one foot at a time and not jump, and then jump as high and fast as possible on landing. After landing, gymnasts were asked to stay on the jumping mat. Flight Time (FT), Contact Time (CT) in milliseconds and Reactive Strength Index (RSI) which is FT to CT ratio were recorded (Markwick et al., 2015).

To determine the anaerobic power of gymnasts the following equation (Lewis formula) was used:

Power (P) = $\sqrt{4.9\ x\ Body\ weight\ (kg)}\ x\ \sqrt{Vertical\ jump\ height\ (cm)}$ *(In this formula 4.9 is constant).*

A camera capable of recording at 120Hz was used for motion capture; it was set perpendicular to the vault table. Reflective markers were placed for a two-dimensional analysis on the nine anatomic landmarks: 1) heel, (2) lateral malleolus, (3) fifth metatarsal, (4) lateral femoral epicondyle, (5) anterior superior iliac, (6) hip, (7) elbow, (8) shoulder, (9) wrist (Örs & Turşak, 2020).

All markers were set on the facing side of the camera. A two-dimension video analysis was conducted by using a tracker software to calculate: (1) take-off angle, (2) penultimate-CT, (3) Take-off-Foot-CT, (4) Hand-CT variables.

IBM-SPSS 20.0 (Armonk, NY) was used for the statistical analysis. Descriptive characteristics of the gymnasts were presented as mean and standard deviation (±SD). The Mann Whitney U test was used for a statistical comparison of the genders. To express the correlations among variables, Spearman correlation coefficients (r) were used. The r value of correlation coefficient was classified as; r≤0.49 weak relationship; 0.50≤r≤0.74 moderate relationship; and r≥0.75 strong relationship as used by Portney and Watkins (2015). A statistical significance level was at p<0.05.

RESULTS

The descriptive data of gymnasts are given in Table 1.

Drop jump contact time, RSI, ProAg-T, 5m-Reaction-Mat, V_Loss_1, V_Loss_2, V_Loss_3, last stride, horizontal and vertical jump, take-off angle, penultimate-CT, take-off-Foot-CT, approach run V10m and velocity usage percentage variables showed no statistically significant differences between genders (p>0.05). A comparison of the variables according to gender is given in Table 2.

Approach run showed statistically significant correlation with chronological age (r=0.66; p=0.002 for female and r=0.96; p<0.001 for male gymnasts), PHV_Distance (r=0.69; p=0.001 for female and r=0.97; p<0.001 for male gymnasts) and biological age (r=0.693;

p=0.001 for female and r=0.965; p<0.001 for male gymnasts) (Table 3).

Correlations among the approach run velocities and the last stride velocity, the horizontal and the vertical velocities on the take-off board are given in Table 4. The approach run velocity showed a statistical significance and positive correlations with V13-8m (respectively for female and male gymnasts; r: 0.86; p<0.001; r: 0.99; p<0.001), V8-3m (respectively for female and male; r: 0.91; p<0.001; r: 0.90; p<0.001) for both female and male gymnasts. Only V_Jump (vertical) showed no statistically significant relationship with the approach run velocity for female gymnasts (p>0.05).

Correlation results among the approach run, explosive power and agility variables are given in Table 5. There was no statistically significant relationship between the approach run velocity and CMJ, DJ-40, RSI, 0-20 m, ProAg-T, 5m-Reaction-Mat for females (p>0.05). Moreover, DJ-CT and RSI showed no statistically significant correlations with the approach run velocity for male gymnasts (p>0.05).

The approach run and kinematic variables showed no statistically significant relationship (p>0.05) except TO-Angle for female gymnasts (r=0.59; p=0.007) (Table 6).

Table 1
Descriptive demographic variables by gender.

Variables	Gender	
	Female (n=20)	Male (n=12)
Training age (years)	7.10±2.40	9.75±2.45
Chronological age (years)	13.26±1.63	16.53±2.95
PHV_Distance (years)	0.65±1.37	0.48±2.31
PHV_age (years)	12.60±0.38	16.05±0.86
Biological age (years)	12.65±1.37	14.48±2.31
Body weight (kg)	2.59±0.30	3.28±0.69
Body height (cm)	147.56±7.06	159.92±12.93
Sitting height (cm)	78.26±3.92	83.59±7.57
Leg length (cm)	69.30±4.27	76.33±5.70
BMI (kg/m^2)	18.02±1.97	20.18±3.50
Body fat percentage (%)	16.82±4.82	10.82±10.23
HG_Total_Relative	1.04±0.14	1.30±0.15

PHV: Peak High Velocity; BMI: Body Mass Index; HG: Hand Grip

Table 2
Comparison of the variables.

Variables	Gender			
	Female (n=12)	Male (n=20)	U	p
CMJ	30.53±3.53	39.06±5.74	21.500	*0.000**
DJ - 40 cm	32.14±4.67	41.87±7.76	29.500	*0.000**
DJ - CT	0.23±0.28	0.24±0.11	77.500	*0.098*
RSI	3.16±1.05	2.89±1.14	91.000	*0.259*
Anaerobic power (watt)	471.87±81.01	727.81±250.21	47.000	*0.004**
0-20 m (s)	3.52±0.15	3.17±0.25	27.500	*0.000**
ProAg-T (s)	5.81±0.49	5.36±0.45	61.000	*0.032*
5m-Reaction-Mat (s)	0.59±0.13	0.59±0.09	106.000	*0.933*
V_Loss_1 (s)	0.37±0.46	0.49±0.44	97.500	*0.381*
V_Loss_2 (s)	-0.30±0.35	-0.19±0.52	109.000	*0.668*
V_Loss_3 (s)	-1.06±0.69	-0.85±0.77	100.000	*0.436*
Last stride (m)	2.62±0.24	2.85±0.36	63.500	*0.055*
Jump (horizontal) (m)	1.81±0.23	1.70±0.29	95.000	*0.330*
Jump (vertical) (m)	0.86±0.15	0.86±0.16	119.500	*0.984*
Take-off-angle (º)	47.52±6.22	45.56±4.45	100.500	*0.448*
Penultimate-CT (s)	0.11±0.01	0.11±0.01	119.000	*0.966*
Take-off-Foot-CT (s)	0.12±0.01	0.11±0.01	70.500	*0.043*
Hand-CT (s)	0.25±0.06	0.18±0.05	32.000	*0.001**
Approach run -V10m- (m/s)	6.67±0.41	7.29±0.90	62.000	*0.024*
20m speed velocity-V10-20m-(m/s)	6.63±0.36	7.53±0.95	34.000	*0.001**
Velocity Usage percentage (%)	100.79±5.74	96.86±4.52	71.500	*0.059*

CMJ: Counter Movement Jump; DJ: Drop Jump; CT: Contact Time; RSI: Reactive Strength Index
*p<0.05

Table 3
Approach run and age variables correlations.

Variables		Chronological age	PHV_Distance	Gender
Approach run velocity -V10m- (m/s)	r	0.66**	0.69**	Female
	p	0.002	0.001	
	r	0.96**	0.97**	Male
	p	p<0.001	p<0.001	

PHV: Peak High Velocity
**p<0.001

Table 4
Approach run and velocity correlations.

Variables		V13-8m	V8-3m	V_Last stride	V_Jump (Horizontal)	V_Jump (vertical)	Gender
Approach run velocity -V10m- (m/s)	r	0.86**	0.91**	0.64**	0.52*	0.15	Female
	p	p<0.001	p<0.001	0.002	0.020	0.519	
	r	0.99**	0.90**	0.90**	0.90**	0.59*	Male
	p	p<0.001	p<0.001	p<0.001	p<0.001	0.045	

*p<0.05
**p<0.001

Table 5
Correlations among the approach run, explosive power and agility variables.

Variables		CMJ	DJ- 40	DJ - CT	RSI	Anaerobic power (watt)	0-20 m	ProAg - T	5m-Reaction -Mat	Gender
Approach run velocity -V10m- (m/s)	r	-0.14	0.34	0.45*	-0.30	0.82**	-0.16	-0.24	0.28	Female
	p	0.550	0.137	0.049	0.195	p<0.001	0.511	.0323	0.268	
	r	0.91**	0.62*	-0.12	0.12	0.95**	-0.90**	-0.78**	-0.62*	Male
	p	p<0.001	0.031	0.713	0.713	p<0.001	p<0.001	0.003	0.031	

CMJ: Counter Movement Jump; DJ: Drop Jump; CT: Contact Time; ProAg - T: Pro Agility Test
*p<0.05
**p<0.001

Table 6
Approach run velocity and kinematic variables correlations

Variables		TO-Angle	Penultimate-CT	TO-Foot-CT	Hand-CT	Gender
Approach run velocity -V10m- (m/s)	r	-0.59**	0.27	0.22	-0.51*	Female
	p	0.007	0.257	0.353	0.023	
	r	-0.55	-0.25	0.44	-0.26	Male
	p	0.067	0.428	0.155	0.418	

TO: Take-off; CT; Contact Time
*p<0.05
**p<0.001

DISCUSSION

The aim of the current study was to investigate the relationship between age, bio-motor and technical components specifically in relation to the approach run velocity and other variables in artistic gymnastics, and differences in genders were looked into as well. While anaerobic power, 0-20 m speed, 20m speed velocity, and hand contact time were found to be different between genders, other variables showed no significant differences. The approach run showed statistically significant correlations with chronological age, PHV_Distance, biological age, V13-8m and V8-3m.

The progress of velocity for the vault run in AG for the last ten years prior to the 2007 World Championships was analysed by Naundorf et al. (2008). According to the results of their study, the maximum approach run velocity of female gymnasts (n=51) during the handspring was reported to be 8.37 m/sec while the moderate approach run velocity for male gymnasts (n=62) was 9.00 m/sec. In the same study, authors compared the approach run velocities from the 2007 and 1997 World Championships and reported that gymnastics became faster for the past 10 years relative to their study year. In the current study, the mean approach run velocity was 6.67 m/sec for female gymnasts and 7.29 m/sec for male gymnasts. As seen from the comparison of our results and Naundorf et al. (2008), there are substantial differences in the approach run velocities. These differences may be attributed to the gymnasts' mean ages. In the current study, their mean age was 13.26±1.63, 16.53±2.95 for women and men respectively. Naundorf et al. (2008) analysed the World Championships and even those gymnasts who participated in the World Championships for the first time were at least 16, therefore female gymnasts were older than in our study. Furthermore, the numbers of gymnasts were also different. While 51 women and 62 men gymnasts were analysed by Naundorf et al. (2008), we analysed 12 women and 20 men gymnasts.

Vaulting in gymnastics has similar characteristics as the long jump and the pole vault in that it involves running toward a target. However, there are less complex post-flight actions in the long jump. Still, it is comparable to the gymnastic vaulting in the approach phase (Bradshaw, 2004). Bayraktar and Cilli (2017) conducted a biomechanical analysis of the long jump and reported that the speed reached at the end of the velocity test was considered the maximum speed. If the approach run speeds are more than 100%, it means that the sprint test was not performed at the maximum speed. The approach run that reaches 90% of the speed ability is considered a good level in many sports (such as long jump) where horizontal speed is important (Bayraktar & Çilli, 2017). Moreover, most of the necessary energy is produced by the run-up velocity; an effective conversion of the optimal run-up speed to the vertical speed at the board and the table is of paramount importance. A high horizontal velocity can create risks for a proper landing. As the gymnast cannot alter his/her horizontal velocity in the air, he/she stops or absorbs it during landing and thus increases his/her chances of a perfect landing (without a forward step). If the horizontal velocity is low, absorbing the horizontal energy at the landing without a step is easier. On the other hand, due to a higher flight phase, an increased impact on landing may increase the risk of injuries. (Eb et al., 2012).

In our results, the approach run velocities and velocity loss were similar for both genders. In vaulting, gymnasts need an adequate linear and angular momentum during the approach run and the table contact to complete the rotational needs in the post-flight phase (Hiley et al., 2015). In other words, as the approach run velocity increases, other components of the element and performance are positively affected. Moreover, the stride frequency and the stride length are considered to be components of the speed run. On the other hand, contact time is a sub-component of stride frequency and the longer the contact time, the greater the loss of speed. In a similar way, flight duration is also stated as a loss of time. In gymnastics, the approach run to the vault is not expected to be performed with a maximum speed run. An optimal approach run will become the basis for the next element. The velocity loss during the mentioned phases may help gymnasts to perform the element to a required quality.

The table contact time has been analysed in previous studies (Takei et al., 2000; Takei 1990; Takei and Kim, 1990, Kwon et al., 1990) and reported to be between 0.16-0.25 seconds. In our study this variable ranged between 0.18-0.25 seconds for both female and male gymnasts. These results seem to support the literature. Moreover, Farana and

Vaverka (2012) reported foot CT as 0.120 seconds and hand CT as 0.156 seconds for high level female gymnasts. In our study the average foot CT and hand CT were found to be 0.120 and 0.250 seconds respectively. While our results regarding the foot CT seem to support the literature, the hand CT of female gymnasts differs substantially from the literature. These differences may be due to the different level of gymnasts participating in each study. Farana and Vaverka (2012) worked with eight top level gymnasts with an average of 19.9 years who competed in a Grand Prix (2010, Ostrava) while our participants were 20 national team members with an average age of 13.3 years. As a result, the takeoff-Foot-CT of gymnasts was similar, but the hand-CT was longer for female gymnasts. The difference may be attributed to the fact that gymnasts in Farana and Vaverka (2012) were in an official competition and their performance may have required difficult movement in the second flight.

When the correlation between anaerobic power and approach run were examined, high correlations were found both for female and male gymnasts. Strength is one of the anaerobic power components. Girls reach PHV at the age of 12 while boys reach PHV at the age of 14 (Malina, Bouchard & Bar-Or, 2004). In the current study, PHV distances were 0.65 and 0.48 in females and males respectively, showing that they have just reached their peak body height. PHV is critical for strength training. However, the relationship between anaerobic power and approach running speed due to strength development determined in this study can be explained by the fact that gymnastics is an early specialisation branch.

Limitations

The current study has the following limitations:

(1) Twenty female and twelve male gymnasts participated in this study.

(2) The kinematic analysis consisted only of Take-off (TO) angles, penultimate CT, TO Foot CT, Hand CT variables.

(3) Only nine markers were put on gymnasts' anatomical landmarks.

CONCLUSIONS

In this study, similarities and differences between genders were determined. The results show that CMJ, DJ-40 cm and 20m speed velocity variables were found to be higher for male than female gymnasts. Furthermore, the 0-20m speed and the hand-CT were higher for female gymnasts. According to the results of our study, the approach run and speed tests did not show any significant correlations for female gymnasts. However, a high correlation was found between the approach run and the 20m speed test for male gymnasts. This may be a proof that male gymnasts use their potential speed in the approach run better than female gymnasts.

Additionally, the relationships among the handspring vault performance components in terms of training elements were determined. In this way, priorities can be set for tests that are used in bio-motor and technical applications that can be conducted by trainers and gymnasts in vault training. In addition, by means of this study, it will be helpful for trainers to evaluate the top performance potential level in gymnasts in relation to their biological age and maturity level.

REFERENCES

Atiković, A. (2012). New regression models to evaluate the relationship between biomechanics of gymnastic vault and initial vault difficulty values. *Journal of Human Kinetics*, *35*(1), 119–126. https://doi.org/10.2478/v10078-012-0085-6

Atiković, A., & Smajlović, N. (2011). Relation between vault difficulty values and biomechanical Parameters in Men ' S Artistic. *Science of Gymnastics Journal*

Online, 3(3), 91–105.

Balyi, I., Way, R., & Higgs, C. (2013). Long-Term athlete development. In Current Sports Medicine Reports (Vol. 9, Issue 6). *Human Kinetics*. https://doi.org/10.1249/jsr.0b013e3181fe3c44

Bayraktar, I., & Çilli, M. (2017). Biomechanical analysis of long and triple jump events (1st ed.). Nobel Publishing.

Bayraktar, I., & Çilli, M. (2018). Estimation of jumping distance using run-up velocity for male long jumpers. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports*, *22*(3), 124. https://doi.org/10.15561/18189172.2018.0302

Bencke, J., Damsgaard, R., Saekmose, A., Jørgensen, P., Jørgensen, K., & Klausen, K. (2002). Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming. *Scandinavian Journal of Medicine and Science in Sports*, *12*(3), 171–178. https://doi.org/10.1034/j.1600-0838.2002.01128.x

Bradshaw, E. (2004). Gymnastics: Target-directed running in gymnastics: A preliminary exploration of vaulting. *Sports Biomechanics*, *3*(1), 125–144. https://doi.org/10.1080/14763140408522834

Bradshaw, E. J., & Rossignol, P. Le. (2004). Gymnastics: Anthropometric and biomechanical field measures of floor and vault ability in 8 to 14 year old talent-selected Gymnasts. *Sports Biomechanics*, *3*(2), 249–262. https://doi.org/10.1080/14763140408522844

Eb, J. Van Der, Filius, M., Rougoor, G., Niel, C. Van, & Water, J. De. (2012). Optimal velocity profiles for vault. *Biomechanics in Sports*, 71–75.

Elizabeth, B., Hume, P., Calton, M., & Aisbett, B. (2010). Reliability and variability of day-to-day vault training measures in artistic gymnastics. *Sports Biomechanics*, *9*(2), 79–97. https://doi.org/10.1080/14763141.2010.488298

Fernandes, S. M. B., Carrara, P., Serrão, J. C., Amadio, A. C., & Mochizuki, L. (2016). Kinematic variables of table vault on artistic gymnastics. *Revista Brasileira de Educação Física e Esporte*, *30*(1), 97–107.

FIG (2016a). Code de Pointage for women's artistic gymnastic competition. Federation Internationale de Gymnastique.

FIG (2016b). Code de Pointage for men's artistic gymnastic competition. Federation Internationale de Gymnastique

Ford, P., de Ste Croix, M., Lloyd, R., Meyers, R., Moosavi, M., Oliver, J., Till, K., & Williams, C. (2011). The Long-Term Athlete Development model: Physiological evidence and application. *Journal of Sports Sciences*, *29*(4), 389–402. https://doi.org/10.1080/02640414.2010.536849

Haigis, T., & Schlegel, K. (2020). The regulatory influence of the visual system: An exploratory study in gymnastics vaulting. *Science of Gymnastics Journal*, *12*(1), 61–73.

Hiley, M. J., Jackson, M. I., & Yeadon, M. R. (2015). Optimal technique for maximal forward rotating vaults in men's gymnastics. *Human Movement Science*, *42*, 117–131. https://doi.org/10.1016/j.humov.2015.05.006

Irwin, G., & Kerwin, D. G. (2009). The influence of the vaulting table on the handspring front somersault. *Sports Biomechanics*, *8*(2), 114–128. https://doi.org/10.1080/14763140902745027

Markwick, W. J., Bird, S. P., Tufano, J. J., Seitz, L. B., & Haff, G. G. (2015). The intraday reliability of the reactive strength index calculated from a drop jump in professional men's basketball. *International Journal of Sports Physiology and Performance*, *10*(4), 482–488. https://doi.org/10.1123/ijspp.2014-0265

Marques, M. C., Van Den Tillaar, R., Gabbett, T. J., Reis, V. M., & González-Badillo, J. J. (2009). Physical fitness qualities of professional volleyball players: Determination of positional differences. *Journal of Strength and Conditioning Research*, *23*(4), 1106–1111. https://doi.org/10.1519/JSC.0b013e31819b78c4

Mirwald, R. L., Baxter-Jones, A. D. G., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*, *34*(4), 689–694. https://doi.org/10.1249/00005768-200204000-00020

Mkaouer, B., Hammoudi-Nassib, S., Amara, S., & Chaabène, H. (2018). Evaluating the physical and basic gymnastics skills assessment for talent identification in men's artistic gymnastics proposed by the International Gymnastics Federation. *Biology of Sport*, *35*(4), 383–392. https://doi.org/10.5114/biolsport.2018.78059

Naundorf, F., Brehmer, S., Knoll, K., Bronst, A., & Wagner, R. (2008). Development of the velocity for vault runs in artistic gymnastics for the last decade. *In ISBS-Conference Proceedings Archive*, 481–484.

Örs, B. S., Cerrah, A. O., Ertan, H., & Bereket Yücel, S. (2017). The relationship between anthropometric, physical, technique components and three different agility tasks in soccer players. *Turkiye Klinikleri Journal of Sports Sciences*, *9*(1), 21–31. https://doi.org/10.5336/sportsci.2016-53826

Örs, B. S., & Turşak, C. The relationship between passive lower limb flexibility and kinematic determinants of split leap performance in rhythmic gymnastics. *Spor Bilimleri Araştırmaları Dergisi*, 5(1), 76-82.

Salam, Z. A., & Jaafar, A. L. F. A. (2020). The effect of special strength training on developing biomechanical variables run up, hurdle during tuck (Tsukahara) Round off Back performance on the jump table. *International Journal of Psychosocial Rehabilitation*, 24(01).

Vescovi, J. D., & McGuigan, M. R. (2008). Relationships between sprinting, agility, and jump ability in female athletes. *Journal of Sports Sciences*, *26*(1), 97–107. https://doi.org/10.1080/02640410701348644

Corresponding author:

Işık BAYRAKTAR
Department of Coaching Education,
Faculty of Sport Sciences, Alanya
Alaaddin Keykubat
University, Alanya, Turkey
Tel: +90 242 510 61 50
E-mail: isik.bayraktar@alanya.edu.tr

Article received: 26.11.2020
Article accepted: 9.2.2021