A COMPARISON OF TIME OF FLIGHT AND HORIZONTAL DISPLACEMENT SCORES IN TRAMPOLINE GYMNASTICS ROUTINES

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Abstract

In trampoline gymnastics, elements with low difficulty values are given more place in the first routines in accordance with the international competition rules. In the second routines, because the difficulty value of all the elements performed earn points for the gymnast, elements with high difficulty values are preferred. This difference may affect other score types in the routines. Accordingly, the aim of this study was to compare the time of flight and horizontal displacement scores in first and second routines. The results of the 2019-2020 Trampoline Gymnastics Turkish Championship constituted the data of the study. In both competitions, both the entire group and the female and male groups were evaluated. Except for the 2019 male horizontal displacement scores, the time of flight and horizontal displacement scores of all groups were found to be statistically significantly lower in the second routines compared with the first routines ($p<0.05$). According to these results, the trampoline gymnasts preferred more complex and difficult elements to obtain high difficulty scores in the second routines in accordance with the international rules, which may have caused them to achieve lower time of flight and horizontal displacement scores compared with the first routines. Trainers and gymnasts should aim to increase the difficulty score without decreasing the total score while choosing elements for second routines. To find this difficulty level, trainings and trial competitions can be performed with routines with different difficulty scores.

Keywords: *trampoline gymnastics, time of flight, horizontal displacement, difficulty.*

INTRODUCTION

Although the birth of trampoline gymnastics dates back to 1934, it has been an Olympic branch since the Sydney 2000 Summer Olympic Games (Federation Internationale De Gymnastique [FIG]) and its popularity has been increasing every year. Although it is a relatively new branch in Turkey and competitions have been regulated since 2006 (Turkish Gymnastics Federation), males aged 17-21 were able to develop quickly enough to win the championship in the Synchronized Competition in 2017 Trampoline Gymnastics World Age Group Competition.

Trampoline exercises are also used as a teaching method for other gymnastics branches and mostly require balance, movement control skills, and visual, kinesthetic, vestibular perception (Atilgan, 2013). Trampoline gymnastics competitions consist of three routines, with each routine comprising ten elements. A routine is characterized by high and rhythmic jumping movements and should include forward and backward somersaults

and twisting movements, although the difficulty level varies according to the age group. All routines must be conducted without interruption and intermediate straight jumps (2017-2020 Code of Points Trampoline Gymnastics, [CoPTG] 2016). Since the difficulty value of each element in the second and the final routine is added to the total score, it is very important to apply elements with high difficulty in these routines. The inability to resume the routines after a fall or a pause distinguishes trampoline gymnastics from other gymnastics branches. A trampoline gymnast has to develop their jumping skills in order to be able to perform technical movements consecutively with the least amount of errors. Thus, the gymnast will have enough time to perform the movement, go to the opening and landing phase, and prepare for the next movement. According to studies, a trampoline gymnast is exposed to 5-7 times their body weight in jumping phases (Briggs, 2014; Vaughan, 1980).

The time of flight (TOF) score, which is calculated with a standard electronic device, is added to the difficulty score, execution score, and horizontal displacement (HD) score in all routines (2017-2020 CoPTG, 2016), although there may be exceptions about diffuculty score by age groups. The TOF score refers to the total time the gymnast stays in the air during the routine and rewards the gymnast who can perform the elements in their routine while maintaining the height (Heinen & Krepela, 2016). The result of the electronic device is added directly to the score of that routine without any action. HD scores are calculated from the gymnast's horizontal displacements on the trampoline bed. The aim is to stay in the center of the trampoline bed and perform the elements without falls or injuries (Ferger, Helm, & Zentgraf, 2020). In addition, the inclusion of different score types in the total score can be specified as another aim. The maximum score that can be obtained in this section is 10. If the gymnast's point of the setting foot is not within the center lines from the first element's landing, the required deduction is applied and the total deduction is subtracted from the number of elements. Although the aforementioned deduction can be made electronically with a FIG-approved device, it can also be made by two judges (nos: 5 & 6) in the absence of the device. The judges watch live images on a screen in front of them from a camera installed on the trampoline to make the necessary deduction. In a study conducted with 25 male gymnasts competing in the Aere Word Cup in Brescia, the results of the electronic system were compared with the results of the judges, and the compatibility rate was 96.4% (Ferger & Hackbarth, 2017). In national competitions, in cases where an image is not available, this evaluation can be made with the naked eye, by the decision of the chair of the judges panel. For the landing of each element, a deduction in the range of 0.0-0.3 points can be applied according to the area where the gymnast sets foot from starting the first element. The score deductions to be applied according to the landing area are shown in Figure 1.

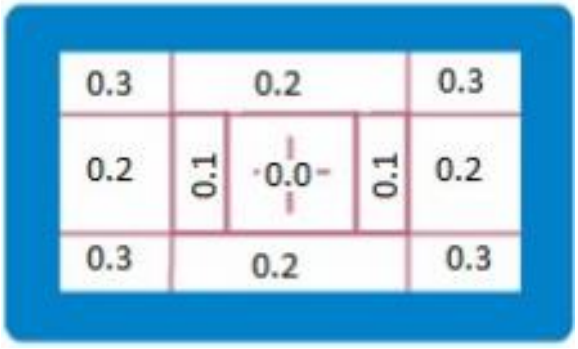

Figure 1. Evaluation of Horizontal Displacement (2017-2020 Code of Points Trampoline Gymnastics, 2016).

With changes according to the age group and the competition type, the difficulty value of at most four elements in the first routine earns points. Therefore, in the first routine, elements with lower difficulty values are mostly used and the

aim is to perform them with the most accurate technique and with the least displacement on the trampoline bed. Given that the difficulty value of each element performed in the second routine and the final routine will earn points for the gymnast, these routines normally include complex elements with high difficulty values. Although it is necessary to improve the jump height and the speed to complete routines consisting of these complex elements, disruptions in the somersault or twist technique during the routine, and a failure to obtain sufficient time for the landing phase may cause the jumping height to decrease. While trying to absorb these mistakes, gymnasts can consciously narrow their jumping. Again, because the second routine consists of elements with high difficulty values, disruptions in the motion technique may cause involuntary displacements in the trampoline bed. In addition, when one of these two parameters is disrupted, it may affect the other negatively during the routine. Accordingly, the TOF and the HD scores of trampoline gymnasts may differ in the first and second routines. When the literature is examined, no studies have investigated this issue. The aim of this study was to compare the TOF and the HD scores of first and second routines (with high diffuculty points) in trampoline gymnastics.

METHODS

The results of the Trampoline Gymnastics Turkish Championships held in Mersin 1-3 March 2019, and 28 February–1 March 2020 constituted the data of this study. To use these results, permission was obtained from the Turkish Gymnastics Federation. In the competition held in 2019, there were male and female trampoline gymnasts in age categories of 10-12, 13-14, 15-16 and 17+ years, and male trampoline gymnasts in the 17-21 years age category; in the competition held in 2020, there were male and female trampoline gymnasts in the age categories of 10-12, 13-14, 15-16, 17-21 and 17+ years. Gymnasts who did not complete 10 elements in either one or both routines were excluded. The TOF and HD scores of the gymnasts who completed 10 elements in both routines were used as our data. In this regard, although the total number of gymnasts participating in the competition in 2019 was 92, the number of gymnasts included in the study was 60, and the number of gymnasts from 2020 included in the study was 63, although the total number of gymnasts participating in the competition was 92. The numbers of gymnasts included in the analysis according to sex and age groups are shown in Table 1. To determine the TOF score in these competitions, an acrosport TMD AS1T device, approved by FIG, was used as the time measuring device. HD scores were calculated by averaging the scores given by the two judges. In addition, according to the rules, there were special requirements that gymnasts had to apply while there were no difficulty points in the 10-12, 13-14 and 15-16 years age groups in the first routines. The difficulty score of two marked elements in the 17-21 years age category and four marked elements in the 17+ years age category was added to the first routine total score. It should be emphasized that in the second routines, as the age of gymnasts grows, the degree of diffuculty of elements increases due to an increased number of somersaults and twisting elements. The difficulty of all elements performed in each age group in the second routines was summed if there was no rule violation and included in the total score of the routine. Basic descriptive analyses were performed; the results are expressed using mean and standard deviation for quantitative variables. A boxplot test was performed to test whether there were any outlier data. The normality of the variables was studied using the Shapiro-Wilk test. Then, a paired-samples t-test was performed. The value of p was adjusted to $p<0.05$. All analyses were

performed using the SPSS Statistics software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY).

Table 1
Number of participants by sex.

Age Categories	2019		2020	
	Female	Male	Female	Male
10-12 years	16	16	18	16
13-14 years	10	4	9	1
15-16 years	7	1	6	4
17-21 years	-	-	-	3
17+ years	3	3	3	3

Table 2
TOF and HD Values in First and Second Routines from 2019.

	n	Mean	St. Dev.	P
First Routine TOF	60	13.50	1.87	
Second Routine TOF	60	13.25	1.58	0.003
First Routine HD	60	9.37	0.27	
				0.014
Second Routine HD	60	9.27	0.26	

Table 3
TOF and HD Values of Female and Male Gymnasts in the First and the Second Routines from 2019.

	Female (n=36) Mean±SD	p	Male (n=24) Mean±SD	p
First Routine TOF	13.61±1.38		13.33±2.46	
Second Routine TOF	13.45±1.27*	0.025	12.96±1.96*	0.040
First Routine HD	9.38±0.27		9.36±0.27	
Second Routine HD	9.23±0.25*	0.009	9.33±0.27	0.619

Table 4
TOF and HD Values in First and Second Routines from 2020.

	n	Mean	Sta. Dev.	p
First Routine TOF	63	13.74	1.71	
Second Routine TOF	63	13.53	1.47	0.001
First Routine HD	63	9.24	0.28	
				0.001
Second Routine HD	63	9.07	0.30	

Table 5
TOF and HD Values of Females and Males in the First and the Second Routines of 2020.

	Female (n=36) Mean±SD	p	Male (n=27) Mean±SD	p
First Routine TOF	13.46±1.62		14.11±1.77	
Second Routine TOF	13.25±1.43*	0.009	13.91±1.47*	0.041
First Routine HD	9.26±0.26		9.22±0.29	
Second Routine HD	9.11±0.31*	0.040	9.01±0.28*	0.001

RESULTS

A paired-samples t-test was used to determine whether there was a statistically significant mean difference between the first and the second routine. Data are shown as mean ± standard deviation, unless otherwise stated. There were no outliers, as assessed in the boxplot test. The assumption of normality was not violated, as assessed using the Shapiro-Wilk test ($p>0.05$). When the results of the 2019 Trampoline Gymnastics Competition were examined, unlike the first routines (13.50±1.87), all participants achieved lower TOF scores in their second routines (13.25±1.58). Second routine TOF scores decreased statistically significantly by 0.243 (95% CI: 0.085-0.401), $t(59)=3.085$, $p<0.005$. Dissimilar to the first routines (9.37±0.27), all participants achieved lower HD scores in the second routines (9.27±0.26). The second routine HD scores decreased statistically significantly by 0.103 (95% CI: 0.021-0.185), $t(59)=2.527$, $p<0.05$. Table 2 shows the 2019 trampoline routine data for TOF and HD.

Female participants jumped lower in the second routine (13.45±1.27) compared with the first routine jump (13.61±1.3), a statistically significant decrease of 0.164 (95% CI: 0.021-0.307), $t(35)=2.335$, $p<0.05$. Dissimilar to the first routines (9.38±0.27), female participants achieved lower HD scores in the second routines (9.23±0.25). The second routine HD scores decreased statistically significantly by 0.153 (95% CI: 0.040-0.265), $t(35)=2.764$, $p<0.05$. Male participants jumped lower in the second routine (12.96±1.96) compared with the first routine jump (13.33±2.46), a statistically significant decrease of 0.363 (95% CI: 0.019-0.707) in TOF scores, $t(23)=2.181$, $p<0.05$. Unlike the first routines (9.36±0.27), male participants achieved lower HD scores in the second routines (9.33±0.27). In the second routine HD scores, the difference (0.029) was not statistically significant (95% CI: 0.090-0.149), $t(23)=0.504$, $p>0.05$. Table 3 shows the 2019 TOF and HD values in the first and the second routines for the female and male gymnasts.

When the results of the 2020 Trampoline Gymnastics Competition were examined, unlike the first routines (13.74±1.71), all participants achieved lower TOF scores in their second routines (13.53±1.47). Second routine TOF scores decreased statistically significantly by 0.207 (95% CI: 0.090-0.324), $t(62) = 3.535$, $p<0.005$. Unlike the first routines (9.24±0.28), all participants achieved lower HD scores in the second routines (9.07±0.30). The second routine HD scores decreased statistically significantly by 0.172 (95% CI: 0.080-0.264), $t(62) = 3.750$, $p<0.005$. Table 4 shows the trampoline routine data for TOF and HD from 2020.

Female participants jumped lower in the second routine (13.25±1.43) as compared with the first routine (13.46±1.62), a statistically significant decrease of 0.215 (95% CI: 0.058-0.372) in TOF scores, $t(35)=2.778$, $p<0.05$. Dissimilar to the first routines (9.26±0.26), female participants achieved lower HD scores in the second routines (9.11±0.31). The second routine HD scores decreased statistically significantly by 0.149 (95% CI: 0.007-0.290), $t(35) = 2.134$, $p<0.05$. Male participants jumped lower in the second routine (13.91±1.47) as compared with the first routine jump (14.11±1.77), a statistically significant decrease of 0.215 (95% CI: 0.058-0.372) in TOF scores, $t(35)=2.778$, $p<0.05$. Unlike the first routines (9.22±0.29), male participants achieved lower HD scores in the second routines (9.01±0.28). The second routine HD scores decreased statistically significantly by 0.149 (95% CI: 0.007-0.290), $t(35) = 2.134$, $p<0.005$. Table 5 shows the TOF and the HD values in the First and the Second Routines from 2020 for the female and male gymnasts.

DISCUSSION

To our knowledge, this is the first study to compare the TOF and the HD scores of first and second routines of trampoline gymnasts. For 2019, when all participants were evaluated together, and when both female and male participants were evaluated separately, TOF scores in each group decreased statistically significantly in the second routines. Only for male gymnasts did HD scores not differ significantly between the first and the second routines. When all group and female participants were evaluated separately, it was clear that the HD scores were significantly lower in the second routine as compared with the first routine. The results of 2020 showed that the TOF and the HD scores were statistically lower in the second routine as compared with the first routine when all participants were evaluated together and when the evaluation was based on sex. Considering these results, the fact that trampoline gymnasts preferred more complex and advanced technique elements to increase the difficulty score in the second routines may have caused them to achieve lower TOF and HD scores than the first routines. It would be useful for trainers and gymnasts to consider these results when designing the second and the final routines.

In trampoline gymnastics, it is important to control the body position throughout the routines, to be able to complete 10 elements in the routines and to perform the elements with minimum errors. There are two basic phases in a trampoline gymnastics element. The first of these can be specified as the flight phase, the second as the contact phase. The contact phase is also divided into the landing phase and the take-off phase. The landing phase is the phase in which the gymnast ends the previous element and slows down, and the take-off phase is the phase in which the gymnast prepares for the next element (Helten, Brock, Müller, & Seidel, 2011). During the landing phase, the gymnast adjusts the lower limb angles and tightness to convert kinetic energy into elastic energy. To use elastic rebound after contact with the trampoline bed, the lower extremity joints are lengthened. This long body position is necessary to keep the energy required for the take-off phase at the maximum level (Qian et al., 2020). In the population in our study, it was shown that the flight phase was shorter in routines created with elements with high difficulty values. This might be because the gymnasts were not able to enter the landing phase in time after performing complex movements and thus not being able to perform the acceleration processes required for the take-off phase well enough. In direct connection to this, jumping height losses, directional distortions, and even increases in errors in the performance of the element can be seen in the next element. In a simulated trampoline gymnastics competition, elite male gymnasts took part in a study and presented two routines and a final routine, just as if they were in a real competition. Considering the counter movement jump results they applied after the first and the second routines, it was seen that there was a significant decrease after the second routine. In addition, when looking at the first 10 jumps of 20 maximal trampoline jump tests, it was found that the results of the post-second routines test were significantly lower than the initial values (Jensen, Scott, Krustrup, & Mohr, 2013). The 20 maximum trampoline jump test is a highly reliable test to measure the performance of trampoline gymnasts (Dyas, Green, Thomas, & Howatson, 2020). The results of this study showed that the gymnast could develop fatigue after each routine in trampoline gymnastics. In the same study, after the warm-up period applied, quadriceps muscle temperature was found to be lower before the second routines than before the first routines (Jensen et al., 2013). Due to

the nature and rules of trampoline gymnastics, the whole group is expected to complete the first routines before starting the second routines. This period can be about half an hour depending on the number of gymnasts in the group. If the gymnasts can not stay active during this time, their body temperature may decrease as shown in the previous study. There are studies in the literature presenting evidence that low muscle temperature can negatively affect performance (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). In this study, in addition to the increase in the difficulty value, fatigue and inability to maintain body temperature may be added to the decrease in the TOF and the HD scores of the second routines. In another study conducted with 11 female trampoline gymnasts with an average age of 10.36 years, the gymnasts performed 20 jumps on the trampoline. Statistically significant differences were found between circulatory and respiratory system variables measured before and after their performance (Mohammed & Joshi, 2015). Similar changes are expected to occur after the first routine is performed during a competition. These physiologic responses may also affect the decrease in the TOF and the HD scores in the second routine.

In a study in which a European Championship was evaluated during the years when HD scores were not included in the scoring, the most important score among the determinants of the total score was the execution score in the qualifying round, followed by TOF and difficulty scores. In the same study, it was stated that the execution score was the most complex part in terms of performance evaluation and that the execution judges were not always consistent in terms of score deductions (Leskošek, Čuk, & Peixoto, 2018). Of course, this discrepancy can be somewhat resolved by including only median marks in scoring and by excluding other marks from scoring. Apart from that, gymnasts should also work on increasing their TOF and HD scores, which show more objective results, to increase their total scores. HD scores were included in the evaluation of trampoline gymnastics total scores in the last cycle (2017-2020 CoPTG, 2016). A high HD score for all routines is important for the total score. In addition, working on the evaluation criteria that give objective results for gymnasts and trainers, supports them motivationally and facilitates the evaluation of success. In terms of increasing the spectatorship of the branch, it can be stated as an important factor that there must be types of scores that can be understood by everyone in the creation of the total/final score (Ferger & Hackbarth, 2017).

It is undeniable that increasing the difficulty score is critical to improving the total score. However, while gymnasts and trainers focus on the difficulty score, they should try to predict whether execution scores, TOF and HD scores, will be adversely affected by this situation and if so, to what extent. In addition, it should not be forgotten that when the results of a competition are examined, even in FIG competitions, gymnasts with lower difficulty points can participate in the finals and even end the competition with a medal. The possible change in TOF and HD scores, which give objective evaluation results, can be examined by trying routines with different difficulty values in trial competitions held during the training period. Of course, due to the natural variability in human movements, the same skill cannot be exactly the same each time it is tried (Bartlett, Wheat, & Robins, 2007). Nevertheless, as these trials are repeated, trainers and gymnasts will be able to get an idea about creating a routine design that will not reduce the total score. For example, if adding 1/1 twisting to the movement to increase the value of an element performed in the middle of a routine by 0.2 points results in lowering TOF and HD scores in most trials, this would negatively affect the continuation of the routine and would be better not to pursue this path.

CONCLUSIONS

The results of this study show that TOF and HD scores may be lower in the second routine as compared with the first routine. The reason for this may be that, unlike in the first routine, all elements in the second routine are included in the calculation of the difficulty value, therefore elements with high difficulty values are preferred in the second routine and this situation negatively affects the landing and the take-off phase. Also, physiologic processes can support this result. In the second routine, especially young gymnasts should know that they can potentially score higher points from other areas of scoring with an optimal difficulty score and thus can obtain a higher total score and set the difficulty score target accordingly. Trainers should work on determining the optimal difficulty score that they can work on without negatively affecting the TOF, the HD and hence maybe the total score, and should train gymnasts accordingly.

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