EVALUATING ROUTINES IN TRAMPOLINE GYMNASTICS

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Original article

Abstract

In trampoline gymnastics, judges' task is to evaluate a particular routine based on the evaluation of overall degree of difficulty, overall skill execution, and the measurement of time of flight duration. The aim of this study was to investigate differences in the three judgment variables between gymnast's age, gymnast's gender, year of competition, and in relation to the final competition standings in trampoline gymnastics. N = 279 datasets from the World Championships and World Age Group Competitions of the years 2011, 2013, 2014, and 2015 served as a database for this study. Results revealed that the judgment variables varied as a function of gymnasts' age, gymnasts' gender, and year of competition. For example, male gymnasts exhibited higher difficulty scores, slightly higher execution scores, higher time of flight scores, and higher total scores as compared to their female counterparts. A similar pattern of results was found when comparing senior gymnasts to gymnasts from younger age groups. Furthermore, all three judgment variables contributed to final competition standings. Difficulty score showed in average a larger contribution while execution score showed in average a tendency to a slightly smaller contribution for male gymnasts, as compared to female gymnasts. From the viewpoint of an individual gymnast, it is concluded that execution score of a routine should be maximized, while time-of-flight score should be optimized given the difficulty that a gymnast is able to present in a particular routine, thereby guaranteeing a safe and deduction-free skill performance.

Keywords: *constraints, degree of difficulty, execution score, time of flight measurement.*

INTRODUCTION

In individual trampoline competitions, athletes perform routines with ten elements, incorporating somersault and twisting movements. In the competition finals, judges' task is to evaluate a particular routine, and to generate a total score for this routine based on the evaluation of overall *degree of difficulty*, overall *skill execution*, and the (recently installed) measurement of *time of flight duration* (as an indicator for gymnasts' overall 'time in the air' during a routine) (FIG, 2013). Although it is stated that judge's end score is an accurate indicator of gymnast's performance (Johns & Brouner, 2012), a validity and reliability evaluation in another acrobatic sports discipline (woman's artistic gymnastics) revealed systematically biased ratings, leading to the conclusion that a deeper analysis concerning scoring in gymnastics should be conducted (Čuk, 2015; Pajek, Kovač, Pajek, & Leskošek, 2014).

Given the current theoretical and empirical evidence, the question arises, which role each of the three aforementioned judgment variables (difficulty, execution, time of flight) plays in the evaluation of routines in trampoline gymnastics? The aim

of this study was therefore to investigate the three judgment variables in relation to gymnast's age and gender, and in relation to the final competition standings in trampoline gymnastics. A particular focus was given to the time-of-flight variable, because it is the latest evaluation criterion in trampoline gymnastics, and there is some initial evidence for a competition-dependent influence on final standings (Luo, & Wang, 2012; Wang, 2013).

The Code of Points comprises the regulations and rules applied to trampoline gymnastics (FIG, 2013). Gymnasts are allowed to perform several initial straight leaps prior to the first scored element of the routine. Depending on the competition type, a particular amount of routines (with and without special requirements) have to be demonstrated in a preliminary contest, while one voluntary routine has to be demonstrated in the finals. In the finals, judges' task is to evaluate these routines (FIG, 2013; Johns & Brouner, 2012). The total score is generated from the following three variables: 1.) *routines' overall degree of difficulty* ('D' score), 2.) *evaluation of routines' execution* ('E' score), and 3.) *measured time of flight* ('T' score). The total score is calculated by summing up each 'D', 'E', and 'T' score. In a last step, penalties, such as wrong clothing or alike, are subtracted from the total score (FIG, 2013).

The degree of difficulty ('D' score) is calculated by summing up the difficulty scores for each presented element in the routine. The difficulty score for each element arises from the amount of somersaults and twist rotations. For example, the value of a complete single somersault is 0.5 points. The value of a complete quadruple somersault is 2.2 points (0.5 points for each of the four somersaults plus 0.1 points for completing each of the two 720 degree rotations). The value of a twist of 180 degrees is 0.1 points. In performances combining twists and somersaults, the corresponding values are summed up. Thus, the higher the difficulty of each of the ten performed elements, the higher the total difficulty score of the routine will be.

The execution score ('E' score) of the routine is calculated by subtracting deductions from the maximum execution score of 10.0 points. The deductions are mainly related to quality aspects of the performed elements, but they also consider additional aspects such as landing outside the landing zone. For example, a poor execution may be seen in the position of the arms, the legs or the body during twisting and somersaulting, or during the opening and landing phase (i.e., a large displacement on trampoline bed). According to the code of points, five judges evaluate the execution score. The highest and lowest scores are neglected and the scores of the remaining three judges are summed up to form the execution score.

The time of flight score ('T' score) is measured electronically. It represents the total time a gymnast was in the air during the presented routine. Time of flight measurements were installed in senior level competitions in 2010 as an additional measurement dimension. The general idea is that gymnasts, who are able to maintain longer flight duration in each element, should be rewarded in final scoring. There are several commercial systems available that measure gymnasts time of flight, such as the AirTime Trampoline System© (http://www.trampolinetimingsystems.com/) or the TMD1©-system and TMD2©-system (http://www.acontests.com/). If the electronic system stops functioning, the time of flight is determined by official video recordings of the routine. The total time of flight constitutes the time of flight score in seconds. The longer the gymnast is in the air during his or her routine, the higher the time of flight score will be.

One could hypothesize that at least the difficulty score and the time of flight score differ with regard to gymnast's age and gender. One usually finds gender differences in muscular strength and muscle architecture in healthy humans (Miller, MacDougall, Tarnopolsky, & Sale, 1993). The same gender difference can often be

found in terms of sport-specific strength for matured athletes from acrobatic sports such as artistic gymnastics (Arkaev & Suchilin, 2004; Bale & Goodway, 1990). In addition, sport-specific strength is likely to vary as a function of gymnasts' age (Calmels, Van Den Borne, Nellen et al., 1995; Lindle, Metter, Lynch, Fleg, Fozard et al., 1997).

We therefore speculated that male trampoline gymnasts exhibit higher difficulty as well as higher time of flight scores than female trampoline gymnasts, and that senior gymnasts exhibit higher difficulty as well as higher time of flight scores than gymnasts from younger age groups, because due to their higher sport-specific strength they are likely able to perform skills of higher difficulty and/or longer flight duration (Brüggemann, 1994; Yeadon & Mikulcik, 2000). The execution score, however, could be unrelated to gymnast's age or gender, assuming, that gymnasts first and foremost perform skills in competition, which they have learned with a high degree of stability and precision.

Differences in the three judgment variables with regard to aspects such as gymnast's age or gender, however, do not necessarily reflect relationships to final competition standings. The additional question would therefore be: Which role plays each of the three variables with regard to final competition standings? Answering this question should help in clarifying the particular contribution of each variable to final competition standings in trampoline gymnastics. To the best of our knowledge, there is for example no conclusive evidence on the role of time of flight measurements as a criterion to discriminate between the performance of different gymnast's (Luo, & Wang, 2012; Wang, 2013). Nevertheless, we hypothesized that all three judgment scores contribute to final competition standings in trampoline gymnastics. There were no specific predictions on the magnitude of these contributions, but we sought to explore the magnitude of these contributions as a function of gymnast's age, and gender.

METHODS

Time-of-flight measurements were installed in (senior level) competitions in 2010. Therefore, individual finals in World Championships and World Age Group Competitions that took place in 2011, 2013, 2014, and 2015 were selected to serve as a database for this study. Individual trampoline results were thus collected for men and women from different age groups. The individual results were gathered from different official internet sources, such as several competition websites, the homepage and document servers of the FIG, or the database servers of several companies providing competition results in trampoline gymnastics. In particular, the total score for each finalist and his or her final rank, as well as the scores for difficulty, execution, and time of flight were noted for later data analysis. Gymnast's age group was categorized either as *senior* (> 18 years; World Championships), as *11-12 years*, *13-14 years*, *15-16 years*, or *17-18 years* (World Age Group Competitions). From the initial N = 320 datasets, 41 datasets had to be removed from the database, because they were denoted as outliers (i.e., very low score due to aborted routine). Thus, a total of N = 279 datasets could be used for later data analysis.

In order to analyze the individual contribution of each judgment variable to final competition standings, the amount of correctly predicted ranks of final competition standings were calculated from the judgment variables. Because the calculation of the final score follows an additive logic (FIG, 2013), the following calculations were performed: In the first step, the percentage of correctly predicted ranks in the final standings was calculated on the basis of the difficulty score only. Therefore, the ranks from gymnasts' difficulty score were compared to final competition standings, and the percentage of correctly predicted ranks was counted. This percentage was defined as difficulty scores'

contribution to prediction accuracy of final competition standings.

In the second step, the percentage of correctly predicted ranks in the final standings was calculated on the basis of the summed difficulty and execution score. Therefore, gymnasts' difficulty and execution score were summed up. The ranks from this summed score were compared to final competition standings, and the percentage of correctly predicted ranks was counted. The difference between this percentage value and the percentage of correctly predicted ranks based on the difficulty score only was defined as the executions scores' contribution to prediction accuracy of final competition standings.

In the third step, the difference between the sum of both contribution values and 100% was defined as the time of flight scores' contribution to prediction accuracy of final competition standings.

A significance criterion of $\alpha = 5\%$ was defined a priori for all reported results. In order to assess differences in difficulty score, execution score, time of flight score, and overall score between male and female gymnasts, between different age groups and between different years of competition, a multivariate analysis of variance (MANOVA) was conducted, including difficulty score, execution score, time-of-flight score, and overall score as dependent variables. In order to estimate the overall contribution of the three judgment variables to final competition standings, an analysis of variance (ANOVA) with repeated measures was conducted, taking the calculated contribution values of the three judgment scores as dependent variables. In order to assess differences in contributions of the judgment variables to final competition standings between male and female gymnasts, between different age groups, and between different years of competition, separate multivariate analyses of variance (MANOVA) were conducted, including the three contribution values as dependent variables.

Gender (male, female), *year of competition* (2011, 2013, 2014, 2015), and *age group* (11-12 years, 13-14 years, 15-16 years, 17-18 years, senior) were treated as between-subject factors for the analyses of variance. In case the MANOVAs showed an overall effect ($p < .10$), separate univariate ANOVAs for each of the dependent variables were calculated. In case an univariate ANOVA showed a significant effect. Fisher LSD post-hoc tests were calculated to explore the structure of the particular effects (Graziano & Raulin, 2012).

RESULTS

Judgment Scores, Gymnast's Age and Gymnast's Gender

The MANOVA showed significant overall main effects of *age group*, Wilks' $\lambda = 0.151$, $F(12, 627.34) = 54.650$, $p < .05$, *year of competition*, Wilks' $\lambda = 0.802$, $F(9, 576.95) = 6.080$, $p < .05$, and *gender*, Wilks' $\lambda = 0.415$, $F(3, 237.00) = 111.45$, $p < .05$. There was an additional significant interaction effect of *age group* x *gender*, Wilks' $\lambda = 0.781$, $F(12, 627.34) = 5.120$, $p < .05$. An overview of the aggregated data can be found in Table 1. When inspecting the separate univariate ANOVAs, the effect of *age group* occurred for difficulty score, $F(4, 239) = 210.130$, $p < .05$, execution score, $F(4, 239) = 12.430$, $p < .05$, time of flight score, $F(4, 239) = 63.100$, $p < .05$, as well as for overall score, $F(4, 239) = 94.500$, $p < .05$. All three judgment variables varied as a function of gymnast's age. In particular, senior gymnasts exhibited in average higher difficulty scores, higher execution scores, and higher time of flight scores, as compared to gymnasts from younger age groups. There were neither differences in difficulty scores, nor in time of flight scores between gymnasts from the age group 15-16 and gymnasts from the age group 17-18. In addition, gymnasts from the age group 11-12 exhibited in average similar execution scores than gymnasts from the age groups 13-14 and 15-16. Gymnasts from the age group 13-14 did not differ in execution score from gymnasts of the age group 15-16. Senior gymnasts exhibited the

Table 1

Gymnast's aggregated difficulty scores, execution scores, time of flight scores, and total scores, differentiated by age group, year of competition and gender (mean ± standard errors)

		Difficulty				Execution				TimeofFlight				TotalScore			
		Female		Male		Female		Male		Female		Male		Female		Male	
AgeGroup	Year	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Age11-12	2011	9.600	0.392	10.175	0.392	23.050	0.566	22.375	0.566	14.093	0.289	13.971	0.289	46.743	0.938	46.521	0.938
	2013	9.125	0.392	10.183	0.453	22.763	0.566	24.100	0.654	14.686	0.289	14.575	0.334	46.573	0.938	48.858	1.084
	2014	9.163	0.392	10.363	0.392	22.913	0.566	22.838	0.566	14.134	0.289	14.771	0.289	46.209	0.938	47.971	0.938
	2015	9.629	0.419	11.071	0.419	24.686	0.605	24.086	0.605	14.882	0.309	15.096	0.309	49.196	1.003	50.254	1.003
Age13-14	2011	11.238	0.392	13.175	0.392	21.600	0.566	23.850	0.566	14.298	0.289	15.508	0.289	47.136	0.938	52.533	0.938
	2013	11.213	0.392	12.275	0.392	24.300	0.566	23.175	0.566	15.557	0.289	15.546	0.289	51.069	0.938	50.996	0.938
	2014	9.586	0.419	12.057	0.419	22.543	0.605	22.414	0.605	14.561	0.309	15.365	0.309	46.690	1.003	49.836	1.003
	2015	10.325	0.392	12.971	0.419	23.363	0.566	23.614	0.605	14.936	0.289	16.288	0.309	48.623	0.938	52.874	1.003
Age15-16	2011	11.650	0.392	14.600	0.453	23.000	0.566	22.900	0.654	14.961	0.289	16.489	0.334	49.611	0.938	53.989	1.084
	2013	12.183	0.453	13.417	0.453	22.400	0.654	23.150	0.654	15.653	0.334	16.675	0.334	50.236	1.084	53.242	1.084
	2014	12.340	0.496	13.500	0.392	22.980	0.716	23.513	0.566	15.411	0.366	16.219	0.289	50.731	1.187	53.232	0.938
	2015	11.986	0.419	13.680	0.496	23.700	0.605	23.040	0.716	15.900	0.309	16.299	0.366	51.586	1.003	53.019	1.187
Age 17-18	2011	10.133	0.453	14.180	0.496	21.700	0.654	22.060	0.716	13.953	0.334	15.847	0.366	45.787	1.084	52.087	1.187
	2013	12.057	0.419	15.540	0.496	22.071	0.605	21.780	0.716	15.421	0.309	16.946	0.366	49.549	1.003	54.266	1.187
	2014	11.263	0.392	14.650	0.453	21.450	0.566	22.700	0.654	15.068	0.289	16.584	0.334	47.781	0.938	53.934	1.084
	2015	11.933	0.453	14.638	0.392	23.100	0.654	23.850	0.566	15.361	0.334	17.134	0.289	50.394	1.084	55.622	0.938
Senior	2011	14.600	0.419	17.000	0.453	24.129	0.605	25.697	0.654	15.825	0.309	17.415	0.334	54.554	1.003	60.111	1.084
	2013	14.143	0.419	16.871	0.419	23.914	0.605	24.129	0.605	15.939	0.309	17.745	0.309	53.996	1.003	58.745	1.003
	2014	14.488	0.392	17.071	0.419	23.175	0.566	24.986	0.605	16.055	0.289	17.450	0.309	53.718	0.938	59.507	1.003
	2015	14.113	0.392	17.267	0.453	24.113	0.566	25.700	0.654	16.101	0.289	18.215	0.334	54.326	0.938	61.182	1.084

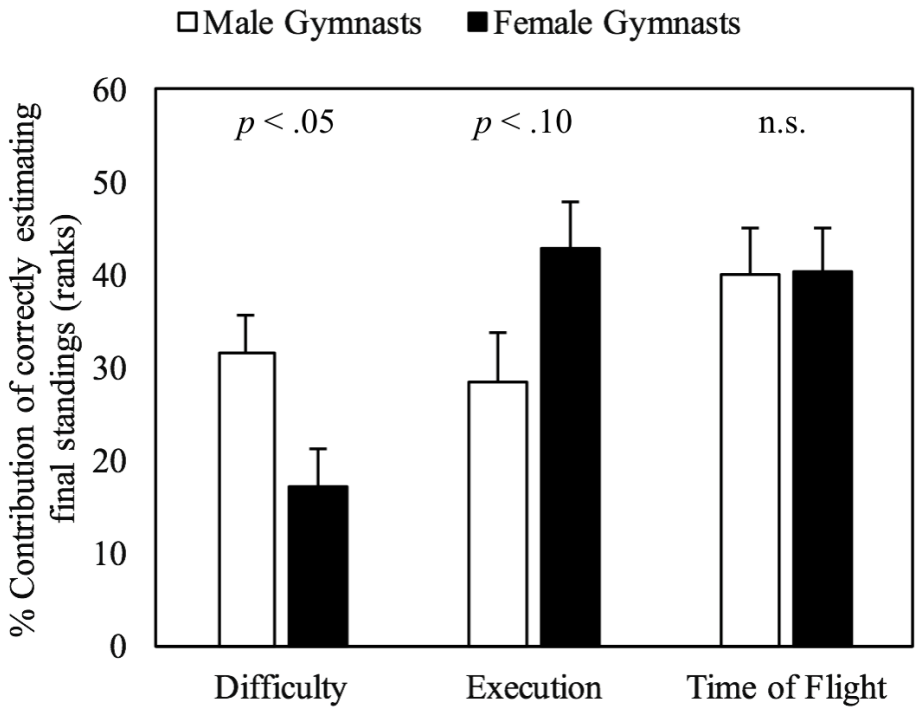

Figure 1. Individual contributions of the three judment variables to correctly estimate final competitions standings (means ± standard errors). Difficulty score showed a larger contribution in male gymnasts as compared to female gymnasts ($p < .05$). Execution score showed a tendency for a smaller contribution in male gymnasts as compared to female gymnasts ($p < .10$).

highest overall scores, followed by gymnasts from the age group 15-16, gymnasts from the age group 17-18, gymnasts from the age group 13-14, and gymnasts from the age group 11-12, while there were no significant differences in overall score between gymnasts from the age group 15-16 and gymnasts from the age group 17-18.An effect of *year of competition* occurred for execution score, $F(3, 239) = 5.260$, $p < .05$, time of flight score, $F(3, 239) = 12.400$, $p < .05$, as well as for overall score, $F(3, 239) = 6.900$, $p < .05$. In average, there were slightly higher execution scores in 2015 as compared to 2014, 2013, and 2011, and there was higher time of flight scores in 2015 as compared to 2014 and 2011. Furthermore, time of flight scores were higher in 2014 and 2013 as compared to 2011. Time of flight scores were lower in 2014, as compared to 2013.

As a consequence of this, total score varied as a function of year of competition. In particular, there were the highest overall scores in 2015, followed by 2013, 2014, and 2011, while there were neither significant differences in overall scores between 2011 and 2014, nor between 2013 and 2014.

An effect of *gender* occurred for difficulty score, $F(1, 239) = 267.040$, $p < .05$, execution score, $F(1, 239) = 5.390$, $p < .05$, time of flight score, $F(1, 239) = 116.100$, $p < .05$, and (as a consequence of this) for overall score, $F(1, 239) = 133.30$, $p < .05$. The interaction effect of *age group* x *gender* occurred for difficulty score, $F(4, 239) = 8.820$, $p < .05$, time of flight score, $F(4, 239) = 9.000$, $p < .05$, as well as overall score, $F(4, 239) = 7.300$, $p < .05$. In average, male gymnasts exhibited higher difficulty scores, slightly higher execution scores, higher time of flight scores, and (as a consequence of this) higher overall scores as compared to female gymnasts. In particular, male gymnasts of all age groups exhibited higher difficulty scores when compared to their female counterparts. Time of flight scores, however, did not differ between

male gymnasts and female gymnasts from the age group 11-12.

Judgment Score's Contributions to Final Standings

Results revealed significant differences between the individual contributions of the three judgment variables, $F(2, 78) = 3.681$, $p < .030$. Difficulty score had an average contribution of 24.30 ± 3.13 % to final competition standings. Execution score contributed in average for 35.57 ± 3.86 %, and time of flight had an average contribution of 40.13 ± 3.36 % to final competition standings. Post-hoc analysis revealed that the contribution of difficulty score was significant smaller than the contribution of time of flight score, while the contribution of difficulty score tended to be significant smaller than the contribution of execution score ($p = .06$). There was no statistically significant difference between the contribution of time of flight score and the contribution of execution score.

Results furthermore revealed neither an overall effect of *age group*, Wilks' $\lambda = 0.768$, $F(8, 68) = 1.201$, $p = .31$, nor of *year of competition*, Wilks' $\lambda = 0.962$, $F(6, 70) = 0.226$, $p = .967$. There was a tendency for an overall effect of *gender*, Wilks' $\lambda = 0.854$, $F(2, 37) = 3.162$, $p = .054$. Inspecting the separate univariate ANOVAs revealed that the effect of gender occurred for difficulty score, $F(1, 38) = 5.870$, $p = .020$, and there was a tendency for execution score, $F(1, 38) = 3.602$, $p = .065$ (see Figure 1). For male gymnasts, the difficulty score showed in average a larger contribution to final competition standings than for female gymnasts, while the execution score showed in average a tendency to a slightly smaller contribution to final competition standings for male gymnasts as compared to female gymnasts. The contribution of time of flight score to final competition standings did not differentiate between male and female gymnasts.

DISCUSSION

Taking the results together, it becomes apparent that male gymnasts exhibited in average higher difficulty scores, slightly higher execution scores, higher time of flight scores, and (as a consequence of this) higher total scores as compared to female gymnasts. Additionally, the three judgment variables varied as a function of gymnasts' age. One could speculate that this might at least in part be explained by age and/or gender differences in muscular strength, and muscle architecture (Bale & Goodway, 1990; Baxter-Jones, 2013; Calmels, Van Den Borne, Nellen et al., 1995; Miller et al., 1993). Senior male trampoline gymnasts for example likely outperform senior female trampoline gymnasts in sport-specific strength, and may thus exhibit longer flight durations (Chen, Zhuo, He, & Zeng, 2006). In turn, longer flight durations might enable the gymnasts to perform skills with higher difficulty (Arkaev & Suchilin, 2004; Yeadon, 2000).

The same skills performed with a longer time in the air may look more spectacular to the judges (Ste-Marie, 2003), likely resulting in a higher execution score. Additionally, athletes have less time constraints to perform a particular skill with adequate precision (i.e., correct opening phase in a somersault and precise landing on the trampoline bed) when having a longer flight phase. This may, however, also depend on the heterogeneity of the field of competitors. Senior gymnasts likely perform more difficult skills than their younger counterparts, so that gymnasts of younger age groups perform more similar in terms of execution or time of flight (Baxter-Jones, 2013; Hume et al., 2013).

Nevertheless, given that in tournaments such as World Championships or World Age Group Competitions the best athletes of the world in their respective age group compete each other, it could likely be that they perform quite similar with regard to their individual routines' difficulty. Subsequent studies could therefore realize a more detailed analysis of competitor's

intraindividual performance variation with regard to the field of competitors in particular competitions.

It should be acknowledged that execution score, time of flight score, and (as a consequence of this) total score varied as a function of year of competition. Competition performance is always the result of a complex interaction of a variety of factors whereas some factors have rather short-term consequences, while others lead to rather long-term consequences (Bradshaw, Hume, & Alsbett, 2012; Kerr & Obel, 2015). For instance, a particular training program could lead to short-term consequences such as muscle soreness the next day, this cause-effect relationship may not be that trivial when it comes to rule changes, such as the installation of time-of-flight recordings in individual trampoline competitions (Cormery, Marcil, & Bouvard, 2008; Rhea, 2004).

The differences in judgment variables between the years could be a result of a delayed effect in gymnasts training schedules, given that rule changes in sport are likely to last up to several years (Liu, 2006). This argument, however, is speculative and needs further empirical investigation. Subsequent studies could utilize a rather qualitative approach by using retrospective interviews with the former gymnasts on topics such as the role of time-of-flight measurements in their training.

Results furthermore revealed that in average the contribution of difficulty score to final competition standings was smaller than the contribution of time of flight score to final competition standings, and it tended to be significant smaller than the contribution of execution score to final competition standings. For male gymnasts, the difficulty score showed in average a larger contribution than for female gymnasts, while the execution score showed in average a tendency to a slightly smaller contribution for male gymnasts as compared to female gymnasts. The contribution of time of flight score did not differentiate between male and female gymnasts. This result follows an additive logic. Difficulty score predicted approximately 31% of final competition standings for male gymnasts, while it accounted for 17% of final competition standings in female gymnasts. When adding execution score for male and female gymnasts, approximately 60% of final standings could be correctly predicted. Adding time of flight scores led to an exhaustive prediction of final competition standings.

It can be concluded that all three judgment scores significantly contribute to the final competition standings, thereby first and foremost differentiating between male and female gymnasts. One could therefore argue that all three judgment variables represent rather distinct evaluation dimensions in trampoline gymnastics. While execution score is mainly based on judges' observation, time-of-flight score is based on a mechanistic measurement. Difficulty score is also based on observation but it comprises a different decision process as compared to the observation of routines' execution. Final competition standings are in average most influenced by time of flight score, and less influenced by difficulty score. This may again reflect that in tournaments such as World Championships or World Age Group Competitions the competitors of their respective competition are more homogeneous in terms of difficulty as compared to execution and time of flight.

While difficulty of a routine can in principle be defined independently of the actual performance of the routine there are several other factors that may for instance influence performance of a routine but not necessarily difficulty of a routine (Davids, Button, & Bennett, 2008; Raab, de Oliveira, & Heinen, 2009). Subsequent studies could for instance try to address questions concerning the performance, and judgment of routines with the same difficulty but different time of flight scores and different execution scores. This approach could help in clarifying the contribution of a particular judgment variables as a function of the other two judgment variables.

Concerning practical implications of this study, it is stated, that difficulty score,

execution score and time-of-flight score are of importance in the evaluation of trampoline routines. From the viewpoint of an individual gymnast, it is argued that execution score of a routine should be maximized by performing to perfection, thereby avoiding deductions. It could furthermore be advantageous if routine difficulty matches (or even excels) the average difficulty level of the other competitors in a particular competition. Time-of-flight score should be optimized for an individual gymnast given the difficulty that he/she is able to present in a particular routine and in order to perform the intended skills under the given constraints, thereby guaranteeing a deduction-free skill execution.

A maximization of time of flight may be not advisable (even thought it has quite a huge weight in predicting final competition standings) due to a lack or inconclusive evidence concerning this parameter (i.e., potential confounding of gymnast's height with time of flight, or potentially higher risk of injury when trying to maximize time of flight without proper technique; Hume, Bradshaw, & Brueggemann, 2015). Although trampoline gymnastics is an Olympic discipline there are still many questions to be answered, and researchers should feel encouraged to approach this highly attractive and evolving sport.

REFERENCES

Arkaev, L.I., & Suchilin, N.G. (2004). *How to create champions. The theory and methodology of training top-class gymnasts*. Oxford: Meyer & Meyer Sport.

Bale, P., & Goodway, J. (1990). Performance variables associated with the competitive gymnast. *Sports Medicine, 10*(3), 139-145.

Baxter-Jones, A. (2013). Growth, maturation, and training. In D.J. Caine, K. Russell, & L. Lim (Eds.), *Handbook of sports medicine and science: gymnastics* (pp. 17-27). Oxford, UK: John Wiley & Sons, Ltd.

Bradshaw, E.J., Hume, P.A., & Alsbett, B. (2012). Performance score variation between days at Australian national and Olympic women's artistic gymnastics competition. *Journal of Sports Sciences, 30*(2), 191-199.

Brüggemann, G.P. (1994). Biomechanics of gymnastic techniques. *Sport Science Reviews*, *3*, 79-120.

Calmels, P., Van Den Borne, I., Nellen, M., Domenach, M., Minaire, P., & Drost, M. (1995). A pilot study of knee isokinetic strength in young, highly trained, female gymnasts. *Isokinetics and Exercise Science, 5*(2), 69-74.

Chen, F., Zhuo, X., He, Y., & Zeng, D. (2006). The analysis about performance level of Fujian trampolinists. *Fujian Sports Science and Technology, 3*, 1-5.

Cormery, B., Marcil, M., & Bouvard, M. (2008). Rule change incidence on physiological characteristics of elite basketball players: a 10-year-period investigation. *British Journal of Sports Medicine, 42*, 25-30.

Čuk, I. (2015). Can audience replace execution judges in male gymnastics? *Science of Gymnastics Journal, 7*(1), 61-68.

Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: a constraints-led approach.* Champaign, IL: Human Kinetics.

Fédération Internationale de Gymnastique (FIG) (2013). Code of Points 2013-2016. Trampoline Gymnastics. Retrieved from http://www.fig-gymnastics.com/publicdir/rules/files/tra/TRA-CoP%202013-2016%20%28English%29.pdf

Graziano, A.M., & Raulin, M.L. (2012). *Research methods: a process of inquiry* (8th ed.). Boston, MA: Pearson Education Inc.

Hume, P.A., Bradshaw, E.J., & Brueggemann, G.-P. (2015). Biomechanics: injury mechanisms and risk factors. In D.J. Caine, K. Russell, & L. Lim (Eds.), *Handbook of sports medicine and science: gymnastics* (pp. 75-84). Oxford, UK: John Wiley & Sons, Ltd.

Johns, P.E., & Brouner, J.W. (2012). The accuracy of judging compared with objective computerised analysis in trampolining. In D.M. Peters, & P.G. O'Donoghue (Eds.), *World Congress of Performance Analysis of Sport IX* (p. 146). Retrieved on January 19th, 2015 from http://www.sportsci.org/2012/WCPAS_IX_Abstracts.pdf.

Kerr, R., & Obel, C. (2015). The disappearance of the perfect 10: evaluating rule changes in women's artistics gymnastics. *History of Sport, 32*(2), 318-331.

Lindle, R.S., Metter, E.J., Lynch, N.A., Fleg, J.L., Fozard, J.L., Tobin, J., Roy, T.A., & Hurley, B.F. (1997). Age and gender comparisons of muscle strength in 654 women and men aged 20-93 yr. *Journal of Applied Physiology, 83*(5), 1581-1587.

Liu, X. (2006). Strategic study on effects of new rule of chinese elite female gymnasts preparation for 2008 Olympic Games. *Journal of Shenyang Sport University, 2*(25), 9-12.

Luo, Y., & Wang, S.-F. (2012). Effect of the individual flight time on the performance of chinese female elite trampolinists. *Journal of PLA Institute of Physical Education, 2*, 66-69.

Miller, A.E.J., MacDougall, J.D., Tarnopolsky, M.A., & Sale, D.G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology, 66*, 254-262.

Pajek, M. B., Kovač, M., Pajek, J., & Leskošek, B. (2014). The judging of artistry components in female gymnastics: a cause for concerns? *Science of Gymnastics Journal, 6*(3), 5-12.

Raab, M., de Oliveira, R.F., & Heinen, T. (2009). How do people perceive and generate options? In M. Raab, H. Hekeren, & J.G. Johnson (Eds.), *Progress in brain research: Vol. 174. mind and motion: The bidirectional link between thought and action* (pp. 49-59). Amsterdam, NL: Elsevier.

Rhea M.R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength and Conditioning Research, 18*, 918–920.

Ste-Marie, D. (2003). Expertise in sport judges and referees: circumventing information-processing limitations. In J.L. Starkes, & K.A. Ericsson (Eds.), *Expert performance in sport* (pp. 169-190). Champaign, IL: Human Kinetics.

Wang, S. (2013). Influence of flight time on trampoline performance of excellent man athletes in China. *Journal of Sports Adult Education, 1*, 77-78.

Yeadon, M. R. & Mikulcik, E. C. (2000). Stability and control of aerial movements. In B. M. Nigg, B. R. MacIntosh, & J. Mester (Eds.), *Biomechanics and Biology of Movement* (pp. 211-221). Champaign, IL: Human Kinetics.

Yeadon, M.R. (2000). Aerial movement. In V.M. Zatsiorsky (Ed.), *Biomechanics in sport. Performance enhancement and injury prevention* (pp. 273-283). Oxford, UK: Blackwell Science Ltd.

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