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TRUNK ROTATIONAL POWER IN FEMALE AND MALE ATHLETES OF GYMNASTICS AND DANCE SPORTS

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Summary. This study investigates between-gender differences in trunk rotational power produced at various loads in athletes of gymnastic and dance sports. A group of 24 female and 15 male competitive aerobic and acrobatic gymnasts, ballroom and rock & roll dancers completed two trials of standing trunk rotations at each side with a barbell of different weights (increasing from 1 kg by ~5 kg up to max. of 20 kg) placed on their shoulders. The power produced during trunk rotations was evaluated using the FiTRO Torso Premium. Results showed significantly higher mean power in the acceleration phase of trunk rotations in male than female athletes at loads of 10.5 kg (206.8 ± 22.0 W and 165.4 ± 17.8 W respectively, $p = 0.033$), 15.5 kg (231.8 ± 27.5 W and 155.6 ± 24.4 W respectively, $p = 0.001$) and 20 kg (196.9 ± 25.3 W and 111.4 ± 20.9 W respectively, $p = 0.001$). Similar significant between-gender differences for angular velocity at weights ≥10.5 kg were observed. Alternatively, power and force were greater at lower velocities in male than female athletes. However, some females were able to produce slightly greater power and force at higher velocities in spite of their lower values at lower velocities when compared to males. This may be ascribed to both the genetic predispositions and the specificity of their acrobatic and dance elements including trunk rotations at various velocities under different load conditions.

Key words: aerobic and acrobatic gymnasts, ballroom dancers, mean power, rock & roll dancers, trunk rotations

Introduction

Core muscle strength plays a significant role in transfering torques and momentum throughout the kinetic chain to the extremities (Shinkle et al. 2012). For instance, effective execution of the golf swing or tennis stroke requires both high limb movement speed and great power production during trunk rotations. Trunk extensors, flexors, rotators, and lateral bend agonists are active throughout the stroke in baseball and tennis as well as the golf swing. All trunk muscles are relatively active during the acceleration phase of the golf swing with the trail-side abdominal oblique muscles showing the highest level of activity (Watkins et al. 1996).

Actually, mean values of power and velocity in the acceleration phase of trunk rotation have been found to be sensitive parameters able to identify group and individual differences (Zemková et al. 2013; Zemková et al. 2014). More specifically, mean power produced with the weight of 20 kg was significantly higher in tennis players than golfers, in rock & roll dancers than ballroom dancers, and in judoists than wrestlers. Comparison of power outputs between individuals showed higher values in ice-hockey player than in karate competitor, in canoeist than in rower, and in weightlifter than in bodybuilder. Furthermore, mean velocity in the acceleration phase of trunk rotation with the weight of 1 kg was significantly higher in tennis players than in golfers. However, its values did not differ significantly between these groups when the weight of 20 kg was used. Significantly higher mean velocity in the acceleration phase of trunk rotation with weights of 1 kg and 20 kg was found in rock & roll dancers as compared to ballroom dancers. On the other hand, there were no significant differences in mean velocity in the acceleration phase of trunk rotation between judoists and wrestlers with weights of 1 kg and 20 kg. There were also individual differences between athletes in mean velocity in the acceleration phase of trunk rotation with weights of 1 kg and 20 kg, i.e. higher values in ice-hockey player than in karate competitor, in canoeist than in rower, and in weightlifter than in bodybuilder.

A comparison of trunk rotational velocity at lower and higher weights (1 kg and 20 kg) in athletes of various sports exercising under different loading conditions revealed significant within and between-group differences (Zemková et al. 2017). Mean velocity in the acceleration phase of trunk rotation with a weight of 1 kg was the highest in ice-hockey players, followed by canoeists, rock & roll dancers, judoists, wrestlers, tennis players, karateists, golfers, and then ballroom dancers. Its values produced during trunk rotations with a weight of 20 kg were the highest in canoeists, followed by ice-hockey players, rock & roll dancers, judoists, wrestlers, tennis players, golfers, karateists, and then ballroom dancers. These findings indicate that such

an assessment of trunk rotational velocity is sensitive in discriminating of athletes of different sports. However, the additional load does not contribute to better differentiation between these groups of athletes.

The question remained as to whether different loads enable better discrimination of athletes. Indeed, sport-specific differences in power-velocity-force profiling during trunk rotations were revealed at loads ≥10.5 kg (Zemková et al. 2020). The highest power is produced by combat sports athletes (boxing, thai boxing, karate, tae kwon do) with a maximum achieved at 10.5 kg, followed by water sports athletes (canoeing, kayaking) with a maximum at 20.0 kg, grappling sports athletes (judo, wrestling) with a maximum at 15.5 kg, and ball sports athletes (golf, hockey, tennis) with a maximum at 10.5 kg (Zemková et al. 2020). Additionally, angular velocity is the highest at lower weights in combat sports athletes and at higher weights in water sports athletes. Alternatively, the highest force is achieved at higher velocities in combat sports athletes and at lower velocities in water sports athletes.

Since body rotations represent one of the essential elements of performance also in athletes of gymnastic and dance sports, we were interested in whether between-gender differences exist in trunk rotational power under various load conditions (Zemková et al. 2022). This study compared power, velocity and force produced during trunk rotations at different weight in female and male aerobic and acrobatic gymnasts, ballroom and rock & roll dancers.

Methods

Participants

Groups of female (n = 24, age 20.1 ± 1.7 years, height 168.5 ± 6.8 cm, body mass 57.5 ± 5.8 kg) and male (n = 15, age 23.1 ± 2.7 years, height 177.9 ± 9.7 cm, body mass 78.3 ± 11.2 kg) competitive aerobic and acrobatic gymnasts, ballroom and rock & roll dancers volunteered to participate in the study. Athletes were all active in particular sports. They were included in the study only if they did not subjectively report back pain. Individuals who had previously undergone surgery or other medically invasive procedures for low back problems were excluded from participation in the study. All of them were informed of the main purpose of the study and related procedures. The procedures followed were in accordance with the ethical standards on human experimentation stated in compliance with the 1964 Helsinki Declaration and its later amendments.

Experimental design

Participants were asked to avoid high intense exercise preceding and during the study. Prior to testing, they were given a demonstration of the proper technique of trunk rotations. The time of day and testing procedures were identical for all participants. The same researchers conducted the testing in all groups. After a warm-up, participants underwent familiarization trials, during which they performed standing rotations of the trunk in a slow and controlled manner while keeping the back straight. Then they performed two repetitions of trunk rotations to each side per load. Bars of different weights were placed on their shoulders behind the neck. The load increased from 1 kg by ~5 kg up to max. of 20 kg. They were asked to perform rotations of the trunk with maximal effort in the acceleration phase. Emphasis was placed on the correct body position during trunk rotations while standing. Participants stood with their feet wider than shoulder width apart and toes slightly pointed outwards while holding the bar on the shoulders with their hands. They rotated their torso from the right (or the left) side towards the opposite side, and then they slowly returned to the starting position. The test was then repeated for the opposite side of the body. They had to engage their core muscles to stiffen the torso and stabilize the spine. A laboratory assistant ensured that participants remained upright throughout the movement and that their head, chest and torso were aligned over the hips. During rotational movement of the trunk with a bar over the shoulders, torque has to be produced to accelerate or decelerate mass on both sides of the bar axis. At the same time, centrifugal forces arise. As long as the weights on both sides of the bar, as well as their rotation radii, remain the same, arising centrifugal forces will be of the same magnitude, although acting in opposite directions. This means they will be fully compensated without putting any stress on the trunk of the subject. In order to quantify the torque produced to accelerate (or decelerate) a rotating bar, one needs to know the mass of the bar and its rotation radius (distance between the center of gravity of rotating masses and the axis of rotation) and instant acceleration. Calculation of the center of gravity of the total rotating masses on both sides (consisting of the bar axis and weight plates) is based on their geometrical dimensions, assuming the same specific mass of the material (iron) used for the bar axis and weight plates. As the rotation radius and masses are set prior to the test, acceleration depends on the subject's effort. For registration of acceleration, the FiTRO Torso Premium (FiTRONiC, Bratislava, Slovakia) was applied. The equipment consists of an inertia measurement unit (a combination of a three-axis accelerometer and three-axis gyroscope) in a small box with an integrated USB interface connected to the computer. While inserted in the bar axis, the inertia measurement unit registers instant angular velocity of rotation movement (rad per second), which is sampled by the computer at a rate of

100 Hz. Special software calculates instant angular acceleration as a derivation of angular velocity. Radius of rotation (the distance between the center of gravity and the axis of rotation) was used for the transformation of angular velocity (rad per second) and angular acceleration (rad per second squared) into real velocity in meters per second and real acceleration in meters per second squared. Torque produced to accelerate or decelerate rotation movement is calculated by multiplying the moment of inertia and the angular acceleration. This is determined by Newton's second law of motion where the force is equated to the product of the mass times the acceleration. Then the power is calculated as the product of force times velocity.

Statistical analysis

The statistical program SPSS for Windows, version 18.0, (SPSS, Inc., Chicago, IL, USA) was used for data analysis. A paired *t*-test was utilized to determine the statistical significance of the differences between mean power in the acceleration phase of trunk rotations in female and male aerobic and acrobatic gymnasts, ballroom dancers, and rock & roll dancers at different weights (1 kg, 5.5 kg, 10.5 kg, 15.5 kg, and 20 kg). The significance level was set at $p < 0.05$. Data is presented as means and standard deviations.

Results

Mean power in the acceleration phase of trunk rotations was significantly higher in male than female athletes at loads of 10.5 kg (206.8 ± 22.0 W and 165.4 ± 17.8 W respectively, $p = 0.033$), 15.5 kg (231.8 ± 27.5 W and 155.6 ± 24.4 W respectively, $p = 0.001$) and 20 kg (196.9 ± 25.3 W and 111.4 ± 20.9 W respectively, $p = 0.001$) (Figure 1 a). Similar significant between-gender differences for angular velocity at weights ≥10.5 kg were observed. Alternatively, power and force were greater at lower velocities in male than female athletes (Figure 1 b, c). However, some females were able to produce slightly greater power and force at higher velocities in spite of their lower values at lower velocities when compared to males. Power produced during trunk rotations at different load showed similar trend also when data of each group, such as acrobatic gymnasts (Figure 2 a), ballroom dancers (Figure 2 b), and rock & roll dancers (Figure 2 c), were analysed.

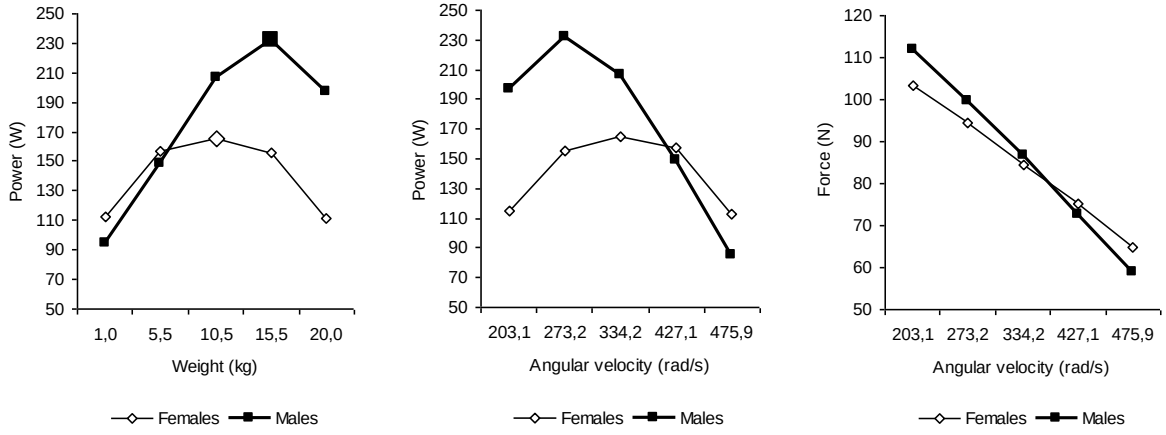


Figure 1

Mean power in the acceleration phase of trunk rotations at different weights (a), power produced during trunk rotations at different velocies (b), and force produced during trunk rotations at different velocies (c) in a group of female and male athletes of gymnastic and dance sports

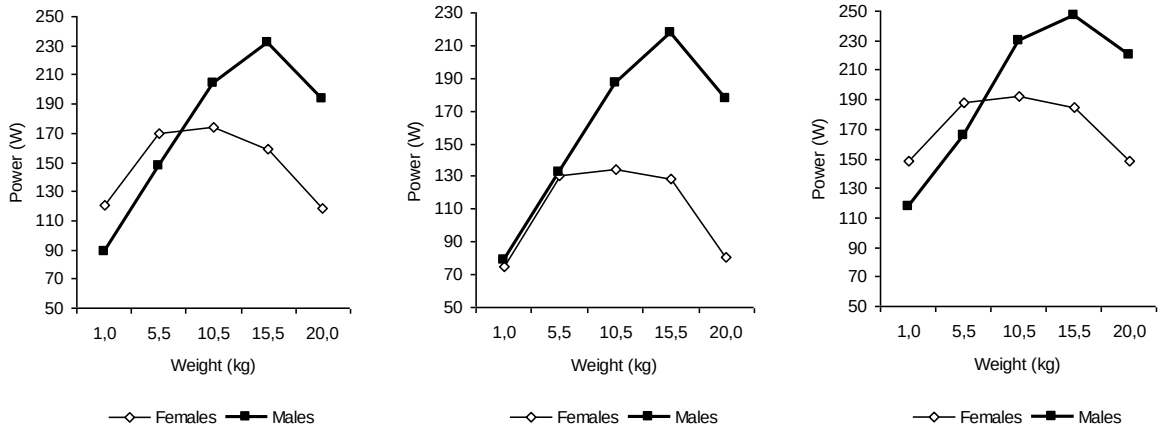


Figure 2

Mean power in the acceleration phase of trunk rotations at different weights in female and male acrobatic gymnasts (a), female and male ballroom dancers (b), and female and male rock & roll dancers (c)

Discussion

Trunk rotational power and velocity were found to be significantly higher in male than female athletes at weights ≥10.5 kg. Alternatively, power and force were significantly higher at lower velocities in male than female athletes. However, some females were able to produce slightly greater power and force at higher velocities in spite of their lower values at lower velocities when compared to males. These between-gender differences in trunk rotational power and velocity may be attributed to specificity of training involving trunk movements of different velocities under different loading conditions. Male athletes need to exert high forces of upper

and lower body in order to lift female counterparts and perform repetitive rotational movements of the trunk.

Core stability and strength represent an integral part of athlete performance in sports based on lifting tasks and trunk rotations, such as rock & roll dancing, gymnastics, aerobic and ballroom dancing. However, in comparison with team sports (e.g., baseball, cricket, football, hockey, netball, soccer, tennis), this is one of a few studies involving athletes of gymnastic and dance sports. There is a lack of research investigating the relationship of body balance and stability of the core with sport-specific performance (Zemková & Zapletalová 2022).

The importance of the core musculature was demonstrated for various tasks, for instance golf swing (Watkins et al. 1996), tennis forehand and backhand strokes (Ellenbecker & Roetert 2004), and baseball pitched ball velocity (Stodden et al. 2001; Aguinaldo et al. 2007). Throwing velocity correlates also with lateral to medial jumps in baseball players (Lehman et al. 2013). Similarly, there is a high correlation between handball-throwing speed and throwing performance with a light but not with a heavy medicine ball (Rivilla-Garcia et al. 2011). However, there is a small shared variance of the scoop medicine ball throw with baseball fielding (agility T-test, standing long jump, and throwing distance) when compared to batting (Kohmura et al. 2008). Also the association of throwing velocity with muscle power highlights its importance for performance in cricket players (Freeston et al. 2016). However, Talukdar et al. (2015) suggests that power obtained from the chop and lift exercise is not an important contributor to throwing velocity in cricket. It seems that general tests have limited applications in testing the specific throwing performance (Rivilla-Garcia et al. 2011).

The demands of joints and muscles proximal and distal to the core in the kinetic chain is necessary to take into account when assessing core muscle strength. The core musculature plays an important role in the transfer of torques and momentum throughout the kinetic chain during sports performance. However, among studies investigating the core stability and core strength in sport, only few of them analyzed force–velocity–power characteristics of exercises involving the use of core muscles (Zemková 2022). Most of them evaluated maximal strengh and endurance of core muscles under isometric and isokinetic conditions. Assessing muscle power during movements involving the use of core muscles close to sport-specific conditions would be more sensitive in revealing within- and between-group differences as well as the efficiency of training programs. For instance, a significant increase of power in the acceleration phase of trunk rotations was observed after both preparatory (at weights from 10 to 26 kg) and competitive training periods (at weights from 6 to 26 kg) in tennis players (Poór & Zemková 2018). Mean power significantly increased also in ice-hockey players after the preparatory (at

weights ≥12 kg) but not after the competitive period (Poór & Zemková 2018). Likewise its values significantly increased in canoeists after the preparatory period only (at weights ≥10 kg) (Poór & Zemková 2018). Similar pre-post training changes were also found for peak values of power (Poór & Zemková 2018). This indicates that muscle power obtained during trunk rotations is able to reflect their training specificity. It also provides useful information for designing training programs aimed at improvements of trunk rotational power under loading conditions. However, further studies are needed to investigate the association of trunk rotational power and velocity with performance variables in athletes of gymnastic and dance sports, as well as their changes during different periods of training.

Conclusion

While the highest power in males is produced at a higher weight of 15.5 kg (in few of them at 20 kg), females are able to generate the highest power at a lower weight of 10.5 kg (or at higher velocities). This may be ascribed to both the genetic predispositions and the specificity of their acrobatic and dance elements including trunk rotations at various velocities under different load conditions.

Acknowledgments

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References

1. AGUINALDO, A. L., J. BUTTERMORE & H. CHAMBERS, 2007. Effects of upper trunk rotation on shoulder joint torque among baseball pitchers of various levels. *Journal of Applied Biomechanics.* **23**, 42–51. doi:10.1123/jab.23.1.42
2. ELLENBECKER, T. S. & E. P. ROETERT, 2004. An isokinetic profile of trunk rotation strength in elite tennis players. *Medicine and Science in Sports and Exercise.* **36**(11), 1959-1963. doi:10.1249/01.mss.0000145469.08559.0e
3. FREESTON, J. L., T. CARTER, G. WHITAKER, O. NICHOLLS & K. B. ROONEY, 2016. Strength and power correlates of throwing velocity on subelite male cricket players.

Journal of Strength and Conditioning Research. 30, 1646–1651. doi:10.1519/JSC.0000000000001246

4. KOHMURA, Y., K. AOKI, H. YOSHIGI, K. SAKURABA & T. YANAGIYA, 2008. Development of a baseball-specific battery of tests and a testing protocol for college baseball players. *Journal of Strength and Conditioning Research.* **22,** 1051–1058. doi:10.1519/JSC.0b013e31816eb4ef
5. LEHMAN, G., E. J. DRINKWATER & D. G. BEHM, 2013. Correlation of throwing velocity to the results of lower-body field tests in male college baseball players. *Journal of Strength and Conditioning Research.* **27**, 902–908. doi:10.1519/JSC.0b013e3182606c79
6. POÓR, O. & E. ZEMKOVÁ, 2018. The effect of training in the preparatory and competitive periods on trunk rotational power in canoeists, ice-hockey players, and tennis players. *Sports (Basel).* **6**, 113. doi: 10.3390/sports6040113
7. RIVILLA-GARCÍA, J., I. MARTÍNEZ, I. GRANDE & J. SAMPEDRO-MOLINUEVO, 2011. Relation between general throwing tests with a medicine ball and specific tests to evaluate throwing velocity with and without opposition in handball. *Journal of Human Sport* and *Exercise.* **6**, 414–426. doi:10.4100/jhse.2011.62.22
8. SHINKLE, J., T. W. NESSER, T. J. DEMCHAK & D. M. MCMANNUS, 2012. Effect of core strength on the measure of power in the extremities. *Journal of Strength and Conditioning Research.* **26**(2), 373-380. doi: 10.1519/JSC.0b013e31822600e5
9. STODDEN, D. F., G. S. FLEISIG, S. P. MCLEAN, S. L. LYMAN & J. R. ANDREWS, 2001. Relationship of pelvis and upper torso kinematics to pitched baseball velocity. *Journal of Applied Biomechanics.* **17**(2), 164–172. doi:10.1123/jab.17.2.164
10. TALUKDAR, K., J. CRONIN, J. ZOIS & A. P. SHARP, 2015. The role of rotational mobility and power on throwing velocity. *Journal of Strength and Conditioning Research.* **29**, 905–911. doi:10.1519/JSC.0000000000000749
11. WATKINS, R. G., G. S. UPPAL, J. PERRY, M. PINK & I. M. DINSAY, 1996. Dynamic electromyographic analysis of trunk musculature in professional golfers. *The American Journal of Sports Medicine.* **24**(4), 535–538. doi:10.1177/036354659602400420
12. ZEMKOVÁ, E., M. JELEŇ, G. OLLÉ & D. HAMAR, 2013. Mean velocity of trunk rotation discriminates athletes with different sport-related demands. *European Journal of Sports Medicine.* **1**(1), 216.
13. ZEMKOVÁ, E., M. JELEŇ, G. OLLÉ, M. CHREN, P. OLEJ, M. ŠTEFANOVSKÝ, L. ZAPLETALOVÁ, J. ŽIŠKA & D. HAMAR, 2014. Mean power and velocity in acceleration phase of trunk rotation in athletes with different explosive force production

capacity. Amsterdam: *19th Annual Congress of the European College of Sport Science*.

14. ZEMKOVÁ, E., M. JELEŇ & D. HAMAR, 2017. Trunk rotational velocites at lower and higher weight in athletes of various sports. Bratislava: *20th International Scientific Conference "From Research to Practice."* p. 151–157.
15. ZEMKOVÁ, E., O. POÓR & M. JELEŇ, 2020. Sport-specific differences in power-velocity-force profiling during trunk rotations at different loads. *Applied Sciences.* **10**(23), 8366. doi:10.3390/app10238366
16. ZEMKOVÁ, E., 2022. Strength and power-related measures in assessing core muscle performance in sport and rehabilitation. *Frontiers in Physiology*. **13**, 861582. doi: 10.3389/fphys.2022.861582
17. ZEMKOVÁ, E., O. KYSELOVIČOVÁ & M. JELEŇ, 2022. Between-gender differences in trunk rotational power in athletes of gymnastic and dance sports. Sevilla: *27th Annual Congress of the European College of Sport Science*.
18. ZEMKOVÁ, E. & L. ZAPLETALOVÁ, 2022. The role of neuromuscular control of postural and core stability in functional movement and athlete performance. *Frontiers in Physiology*. **13,** 796097. doi: 10.3389/fphys.2022.796097