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A COMPARISON OF CONTRACTILE PARAMETERS AMONG TWELVE SKELETAL MUSCLES OF INTER-DANCE COUPLES

ANALIZA MED-MIŠIČNIH KONTRAKTILNIH LASTNOSTI PRI PLESNIH PARIH

ABSTRACT

Dancesport is one of the younger and less-researched sports and involves an emphasis on the energy and the informational component of motorics and on aesthetics. A co-ordinated long-term body movement pattern is essential for learning and adapting the body's efficiency to master dancesport. Therefore, the goal of our research was to analyse intra-muscular contractile parameters in inter-dance couples. Using the tensiomyographic method, we measured the intrinsic mechanic contractile properties of 12 skeletal muscles in 16 participants (eight dance couples, men 19.1 ± 3.6 years; women 18.3 ± 3.2 years). We found that inter-couple asymmetries are present where males have faster gastrocnemius and hand extensor muscles and in females' quadriceps and upper back muscles. Inter-couple symmetry was presented as the quotient between the contraction time of the male and female dancer in each couple. In some muscles we could observe a more than 50% deviation, especially for biceps femoris, rectus femoris, tibialis anterior and latissimus dorsi muscles. In the conclusion we confirm lateral and gender-based differences in dance couples. The average differences are logical consequences of male/female roles in dancing, while individual differences are sometimes quite large and should be treated with care by special coaches and choreographers.

Keywords: skeletal muscle, contraction time, lateral symmetry, tensiomyography, inter-couple symmetry

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POVZETEK

Športni ples je med mlajšimi in manj raziskanimi športi, s poudarkom na energijsko intenzivnih procesih, informacijsko bogate komponente motorike in estetike. Dolgoročno koordinirano gibanje in usklajeno telo sta ključna za uspešno učenje in učinkovitost pri usvajanju plesnih veščin. Zato je bil cilj naše naloge analiza med-mišičnih kontraktilnih lastnosti pri plesnih parih. Z uporabo tenziomiografije smo izmerili kontraktilne lastnosti 12 mišičnih parov na 16 plesalcih – 8 plesnih parov slovenske državne reprezentance (moški 19.1 ± 3.6 let; ženske 18.3 ± 3.2 let). Ugotovili smo, da imajo moški hitrejšo mišico gastrocnemius in mišice iztegovalke komolca, medtem, ko imajo ženske hitrejše mišice iztegovalke kolena in mišice zgornjega dela hrbta. Individualno simetrijo plesnega para smo izračunali kot razmerje med časoma krčenja mišice za moškega in žensko (v odstotkih). Ugotovili smo, da je asimetrija lahko celo večja od 50 %, predvsem za naslednje mišice: biceps femoris, rectus femoris, tibialis anterior in latissimus dorsi. Povzamemo lahko, da obstajajo lateralne razlike in razlike med spoloma plesnih parov. Povprečne razlike so logično razložene z različnimi vlogami obeh spolov znotraj plesnega para, medtem, ko individualne razlike lahko značilno odstopajo od tega. Tovrstna testiranja lahko predstavljajo pomemben pripomoček trenerjem pri dimenzioniranju obremenitev plesnih parov oziroma kreiranju koreografij.

Ključne besede: skeletna mišica, čas krčenja, lateralna simetrija, tenziomiografija, simetrija med soplesalce-ma

INTRODUCTION

Dancesport is one of the youngest and less-researched sports. Competition is held in five standard and five Latin-American dances which differ in their style, rhythm, tempo and basic character. On one hand, dancesport emphasises aerobic and anaerobic components and, on the other, aesthetics – with relaxed and easy movements being important (Zagorc & Jarc-Šifrar, 2003). The results of an investigation of heart rate values (Zagorc et al., 1999) showed that sports dancers (male and female) carry out most dances at the level of a high-intensity load (average 154 and 187.3 beats/min, respectively), and half of the competition time was spent on the level of a 70-80% load.

Dance disciplines incorporate various types of movements in a single event, like fast, sudden and periodic elements with elements of endurance to ensure that the quickness of the dancing elements does not fade and remains appropriate for all the time in a dance show. Professional dancers have a 90% risk of injury during their career, where the lower extremities are involved in approximately 75% of the injuries dancers sustain (Schoene, 2007).s Inter-couple symmetries are very important and mostly dictate the team forming and necessary coaching techniques to ensure couples' adequacy. Knowing that man-leadership in dancing disciplines demands very active performances with fast and load-resistant moves does not mean that women are passive or pushed around. They should also have the elements of speed and strength in their performances. Usually agonistic (men) to antagonistic (women) moves are present or *vice versa* in the dancing elements when both of them face each other. Obviously, some asymmetries should be present but the question remains: *Should they be diminished or are they necessary for a better performance?*

The effect of specific training adapts the human body and the muscular system in many ways, not always just in skeletal muscle strength/endurance directions but also in terms of muscle belly stiffness (Pišot et al. 2008) and contraction time (Šimunič et al., 2011), that can be assessed with tensiomyography (TMG). Further, skeletal muscle belly stiffness, measured with TMG, is a well recognised measure of skeletal muscle tone that reflects skeletal muscle architecture changes after physical conditioning (Pišot et al., 2008; De Boer et al., 2008). In addition, contraction time, measured with TMG, correlates to type I muscle fibres and represents a valid measure for estimating muscle composition (Dahmane et al., 2000, 2005; Šimunič et al., 2011). This makes TMG a suitable skeletal muscle assessment method for studying intra-muscular symmetries in contractile properties between males and females of dance couples. As far as we are aware, there is no easy, objective and selective method available for measuring whole body muscle symmetry in athletes/dancers. Further, in dancesport symmetry or asymmetry are clearly very important.

Therefore, the aim of our study was to assess symmetries in dance couples between 12 skeletal muscles that are regularly involved in sport. We compared lateral sites in 12 of the most important skeletal muscles, and analysed individual inter-couple symmetries in the same muscles.

METHOD

Participants

Sixteen participants – eight dance couples (average age: men 19.1 ± 3.6 years; women 18.3 ± 3.2 years) with no history of neuromuscular disorders volunteered for the investigation (Table 1). All the dance couples were members of the Slovenian national team that regularly competes in high-level competitions. Each participant was fully informed about the possible risks and nature of the experiments and signed an informed consent form. Participants were seated or lay down in a relaxed position on a straight back chair or table depending on the muscle being measured. Isometric conditions were assured using additional elastic straps. All measurements were conducted according to the 1964 Declaration of Helsinki.

Table 1: Basic morphological data for the dance couples

Dance couple	Male			Female		
	Age /years	**Height /cm**	**Weight /kg**	**Age /years**	**Height /cm**	**Weight /kg**
JB_JŠ	24	176	70	23	158	50
JB_DP	19	176	70	19	164	49
DK_MN	24	184	74	21	175	58
BP_IB	21	183	73	21	165	56
VN_ŠB	16	177	61	16	168	59
MV_AD	16	181	65	15	168	44
MK_ŠK	15	185	75	14	172	63
MN_MP	18	178	63	17	168	53
Average	**19.1**	**180.0**	**68.9**	**18.3**	**167.3**	**54.0**
SD	**3.6**	**3.7**	**5.3**	**3.2**	**5.1**	**6.2**

Tensiomyographic measurements

The principles of the tensiomyographic (TMG) method were previously introduced frequently and in detail (Valenčič 1990; Valenčič & Knez, 1997; Šimunič et al., 2010) and evaluated with histological results (Dahmane et al. 2000 and 2005; Šimunič et al., 2011), electromyography (Krševan et al., 2002) and force/torque measurements (Knez et al., 1999; Šimunič, 2003; Šimunič et al., 2010). The variability of the methods was tested and reported as low (Šimunič, 2001; Križaj et al., 2008; Tous-Fajardo et al., 2010), allowing longitudinal studies of muscles' contractile properties.

Our previous observations showed there is no effect of adipose tissue on the results (Šimunič et al., 2010). The TMG measuring point was chosen at the thickest part of the muscle belly. The thickest part of the muscle belly was identified visually and through a few measured TMG responses at different surrounding locations fixed at a position where the largest response was obtained. A displacement sensor was set perpendicularly on a measuring point for detecting skeletal muscle belly thickening. The maximal twitch stimulation amplitude was used for eliciting muscle contraction and the result of the measurement was an amplitude-time curve describing muscle contractile properties.

Electrical stimulation

Two circular (5 or 3 cm in diameter depending on the muscle belly size), self-adhesive electrodes (Axelgaard, Pulse) were placed bipolarly on the skin above the muscle belly. The diameter of the electrodes was chosen on the basis of the muscle size to avoid activation of the synergistic muscles or co-activation. Electrodes were placed 5 cm medially and laterally from the measuring point. A single rectangular monophasic pulse of 1 ms duration from the electro-stimulator (TMG-S1, Furlan & Co. Ltd.) was delivered to the electrodes, transcutaneously eliciting a twitch muscle contraction.

Signal recordings

The TMG signals were stored on a portable PC. The digital TMG signal was directly sampled with the Matlab Compiler Toolbox using a sampling frequency of 1 kHz. Two maximal responses were stored and averaged for further analyses. The maximal stimulation amplitude was identified as the minimal stimulation amplitude needed for the response with the highest displacement-amplitude (Dm).

Four time parameters as a measure for contractile dynamics were calculated from the response:

- **Delay time (Td)** as the time between the electrical impulse and 10% of the contraction;
- **Contraction time (Tc)** as the time between 10% and 90% of the contraction;
- **Sustain time (Ts)** as the time between 50% of the contraction and 50% of the relaxation; and
- **Relaxation time (Tr)** as the time between 90% and 50% of the relaxation.

Measured muscles

Twelve muscles were chosen on both lateral sides regarding the dancesport the participants are involved in:

Two hand muscles:

- *biceps brachii* (BB)
- *triceps brachii* (TB)

Eight leg muscles:

- *vastus lateralis* (VL)
- *vastus medialis* (VM)
- *rectus femoris* (RF)
- *biceps femoris* (BF)
- *gastrocnemius medialis* (GM)
- *gastrocnemius lateralis* (GL)
- *tibialis anterior* (TA)

Three back/trunk muscles:

- *latissimus dorsi* (LD)
- *erector spinae* (ES)
- *obliques externus* (OE)

Statistics

All of the data are presented as means with a standard deviation. The statistical analysis included one-way ANOVA for comparing the averages of two groups of data. An alpha of $p < 0.05$ was considered statistically significant for all the comparisons.

RESULTS

Table 2 presents the average (± SD) values of Td, Tc, Ts and Tr for both genders. The results are grouped for different muscles on both lateral sides. The comparison between both sexes for the 12 measured muscles was tested using the ANOVA variance test and significant differences were marked with "*" at $p < 0.05$.

Body segmental analysis yields a cross-sectional analysis of both genders in high performance dance couples:

UPPER LIMB: The males have a 10% shorter Tc in the right TB, but the females have 26% and 22%, respectively, shorter Ts and Tr in the right and left TB.

TORSO: The females have a 10% shorter Tc in the right LD and a 12% shorter Tc in the left LD. Further, the females have an 11% shorter Td in the right ES and a 7% shorter Td in the left ES. Ts and Tr are both 40% to 47% shorter in the females' ES.

UPPER LEG: The females have a 9% shorter Tc in the right VM and an 18% shorter Tc in the left RF. Moreover, both vastii muscles on both lateral sides have a shorter Td in the females. Only the left RF has a shorter Ts and Tr.

LOWER LEG: The males have a shorter Tc in the GM but significantly just on the right side by 15%, while they have a 16% longer Tc in the left TA.

Table 2: Average values ± SD of four contractile parameters (Td, Tc, Ts and Tr)

Muscle	Side	Td / ms ± SD		Tc / ms ± SD		Ts / ms ± SD		Tr / ms ± SD	
		M	F	M	F	M	F	M	F
m.BB	R	27.0±1.3	26.5±1.8	32.6±4.2	33.2±4.4	171±37.3	156±31.5	105.9±41.2	100±31.4
m.BB	L	26.9±1.7	27.5±2.2	33.5±2.5	33.7±3.9	170±35.6	151±30.8	109.5±42.7	93.4±26.8
m.TB	R	22.3±1.5	22.6±1.8	**21.0±2.6***	**23.2±3.2***	**200±26.1***	**149±36.4***	**109.6±25.0***	**70.5±26.9***
m.TB	L	22.0±1.7	22.4±1.8	22.1±3.5	22.3±2.1	**202±28.6***	**157±35.6***	**119.6±31.4***	**71.6±27.1***
m.LD	R	23.7±2.0	22.2±3.6	**34.2±4.5***	**30.8±3.5***	111±34.2	101±44.7	66.1±26.2	50.7±34.6
m.LD	L	23.9±2.6	24.2±4.3	**33.2±6.8***	**29.2±5.4***	136±20.8	141±41.2	90.5±22.2	74.2±25.7
m.VL	R	**23.3±13***	**21.6±1.7***	22.6±2.4	20.6±2.6	160±43.9	118±68.6	91.8±46.0	75.4±57.7
m.VL	L	**23.7±1.7***	**22.2±1.4***	23.3±2.7	22.2±1.8	135±43.3	119±51.6	87.9±40.6	71.7±42.0
m.VM	R	**22.8±0.9***	**21.8±1.2***	**25.7±1.4***	**23.4±1.5***	226±31.0	221±15.0	48.9±11.7	65.7±51.1
m.VM	L	**23.3±0.8***	**22.5±1.1***	26.5±1.8	25.3±1.8	222±33.0	209±13.7	64.6±41.9	43.9±12.9
m.RF	R	24.6±2.4	23.2±1.6	32.9±5.8	28.0±6.0	169±21.4	175±19.0	114.3±27.1	129±21.2
m.RF	L	25.3±1.9	24.2±1.9	**35.5±6.5***	**29.0±4.5***	**171±20.0***	**97.2±58.0***	**124.1±23.7***	**53.5±46.5***
m.BF	R	25.5±3.2	25.8±1.8	34.2±7.7	32.4±7.5	209±27.0	204±27.6	**50.5±8.7***	**61.9±12.8***
m.BF	L	24.4±2.4	25.3±1.7	34.3±9.1	34.1±9.2	211±17.7	205±31.7	56.0±8.0	57.9±6.3
m.GM	R	20.7±1.6	20.5±1.6	23.5±2.5	25.4±2.4	**209±31.5**	**184±20.0***	**48.0±19.9***	**79.0±43.9***
m.GM	L	20.6±1.6	21.1±2.0	**23.2±1.6***	**27.3±4.4***	**213±33.4**	**173±53.5***	47.5±23.4	75.4±49.6
m.GL	R	20.6±2.3	20.7±1.7	22.6±5.5	24.0±3.6	188±38.7	190±15.8	**69.6±31.2***	**49.0±8.5***
m.GL	L	20.9±1.4	21.4±2.0	23.9±5.4	24.1±3.4	183±25.8	183±22.0	**43.3±9.7***	**55.1±11.6***

Muscle	Side	Td / ms ± SD		Tc / ms ± SD		Ts / ms ± SD		Tr / ms ± SD	
		M	F	M	F	M	F	M	F
m.TA	**R**	26.4±2.0	25.3±2.3	33.4±6.9	31.9±6.7	139±13.7	151±1.0	43.7±8.9	48.4±7.1
m.TA	**L**	**26.9±2.1***	**25.1±1.9***	**34.2±5.3***	**28.7±3.5***	157±25.5	170±9.5	55.5±15.1	58.5±4.5
m.ES	**R**	**20.9±1.0***	**18.7±1.3***	18.3±2.2	17.4±2.2	**214±54.1***	**122±97.7***	**178.1±63.8***	**98.6±92.1***
m.ES	**L**	**20.7±0.9***	**19.2±1.1***	17.5±2.2	17.0±1.4	**194±69.7***	**116±91.3***	158.9±71.4	94.3±88.6
m.OE	**R**	24.9±1.5	24.6±1.5	25.8±3.6	26.1±2.7	141±72.1	126±36.7	96.3±58.7	87.8±34.3
m.OE	**L**	25.2±2.3	24.5±2.6	25.4±4.3	26.4±2.9	114±46.2	113±54.6	72.6±33.6	89.3±52.0

* Indicates a statistically significant difference (p≤0.05)

Inter-couple synchronisation was presented by comparing male and female dancers from the same dancing couple. The results presented in Figure 1 demonstrate the relative difference in Tc. The relative difference was calculated as a quotient between the females' Tc and the males' Tc. Therefore, negative values represent a shorter Tc for a female partner and positive values a shorter Tc in a male partner. Further, a shorter Tc means faster muscle contraction and correlates to less Type 1 muscle fibres within the muscle (Dahmane et al., 2000 and 2005; Šimunič et al., 2011).

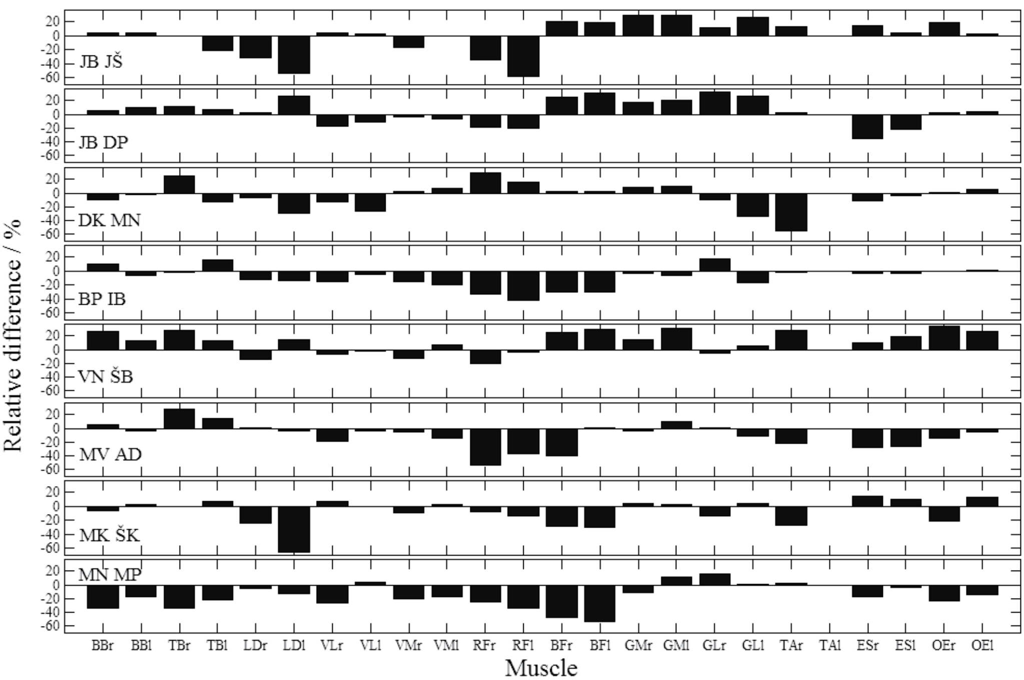

Figure 1: Inter-couple relative differences (symmetry) of Tc in all 12 measured muscles. Results for muscles on both lateral sides are presented (indexed r...right and l...left). Positive percentages represent a lower Tc for the males and negative values a lower Tc for the females.

DISCUSSION

This study investigates skeletal muscle contractile properties of eight top-level Slovenian dance couples. The results of all eight couples (16 participants) were included in the analysis. The sample size was relatively small as we wanted to keep the level of homogeneity high. We compared TMG-measured contractile parameters between both lateral sides and between both dancers (genders) in a couple. As far as we are aware, this study is the only study to analyse the symmetry of contractile parameters of skeletal muscles in dance couples.

In the first analysis of four contractile parameters (Td, Tc, Ts and Tr) of 12 muscle pairs we found some interesting data. The males have a shorter Tc in the TB, while the females have a shorter Tc in the LD. This reflects the leading function of the males. A male partner initiates the dance move while the female partner follows, with some delay, and both finish it simultaneously. For the rest of the trunk muscles we did not find any significant discrepancies.

It is well known that females wear high heels when dancing, which hinders them from using the reactive elasticity of their tendons upon feet impacts. Therefore, the Achilles tendon is less functional in female dancing. In this sense, it is quite understandable that the females have developed faster quadriceps muscles (a shorter Tc) VM and RF, while the males have a faster gastrocnemius medialis (GM). The non-gravitational muscle BF is not affected by gender.

The ergonomics of shoe wear, the leading role in a dance couple, the quickness and aesthetics of the moves and the face-to-face stance of dancers interact with their body characteristics and functionality. Within the body, asymmetry is developed as well as inter-couple asymmetry. If the first one can be explained by dance biomechanics the latter one needs further investigation. It is always a simple question of whether asymmetry should be developed and present or not. Our study presents preliminary results (Figure 1) on inter-couple asymmetry calculated from the quickness of muscle contraction (Tc). We found some interesting data that show for each observed couple an asymmetry spectrum for all measured muscles. Cross-sectioning this data with Table 2 averages coaches can understand the asymmetry developed with the asymmetry needed for dancing. Genetic predisposition is omitted from our data interpretation but we know from our previous work on non-athletes that the BF is the only skeletal muscle where females have a longer Tc (Šimunič et al., 2005).

Research in dancesport is very limited and it is therefore very hard to link the results with others. Kulas et al. (2006) performed a bioimpedance and biomechanics study on highly trained female dancers. During impact and stabilisation phases it was found that the ankle and knee joints absorbed 75% while the knee and hip joints also absorbed 75% of the energy, respectively. While Decker et al. (2003) found that female athletes have a greater joint range of motions and maximum joint angular velocities compared to males. Females also exhibited greater energy absorption and peak powers from the knee extensors and ankle plantar-flexors compared to males. This would increase the risk of an anterior cruciate ligament injury, especially if the landing phase is not completed with an erect posture. We may correlate our data with those of Decker where we found significantly shorter contraction times in the knee extensors and also in the lower back muscles. The risk of injury is substantial in dance. Schoene (2007) reported that every dancer has a 90% probability of an injury in their career where 75% are injuries to the lower extremities. Kadel (2006) further investigated and confirmed that developed overuse injuries in dancers are very common and are very hard to treat.

CONCLUSIONS

Results accompanied by a quality interpretation are very welcomed by coaches as they allow them to see the true potential of dancers when designing the choreography or even composing the couples. Coaches should monitor such muscle adaptation more often at different training or competition periods during the year. Dance-related muscle changes are facilitated by dance specifics – but are they also good for one's posture? Yes and no – dance training may cause a stressful alignment like a lifted rib cage. Such warnings should be identified from the results and compensating elements of the exercise should be incorporated into the training process to diminish this. All of these facts suggest that organised and strict work should be undertaken to maintain health, reduce the risk of injuries and ensure proper body development in dancers and this should form part of a detailed annual health screening programme for all professional dancers.

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