Original Article

Isokinetic knee muscular strength is associated with hematologic variables in female modern dancers

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ABSTRACT

It is important to expose the risk factor in injury in the context of the health and the careers of dancers. Female are at greater risk of developing anemia than men, yet scarce data exist on anemia associated outcomes in female dancers. The aim of the present study was to investigate the relationships between bilateral isokinetic knee extensor and flexor muscles strength, and biochemical hematologic parameters in female modern dancers. Concentric isokinetic peak torque [(PT)-N.m], peak torque % body weight [(PT%BW)-N.m.kg^{-1}], average peak torque [(AVGPT)-N.m] and total work [(TW)-J)] of the knee extensor and flexor muscles were measured at a velocity of 60º, 180º and 300ºs^{-1}. To determine hematological parameters [red blood cell count (RBC), hematocrit (Hct), and Hb] were determined. The dancers of LHG and HHG had significant differences ($p \leq 0.05$) for hematological parameters. HHG dancers' strength production in extensors muscles of PT, TW and AVGPT in non-dominant left leg ($p \leq 0.05$) were significantly higher than LHG dancers. There were significant ($p \leq 0.05$) negative correlations between TW (300ºs^{-1}) of left leg extensor muscles and RBC, Hct and Hb variables. Isokinetic knee muscular strength is associated with hematologic variables in female modern dancers. The current study provides evidence that the low-level hematologic parameters has decreased performance on torque production of extensors knee muscles in non-dominant leg during

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isokinetic muscle strength endurance in female modern dancers. **Key words:** HEMOGLOBIN, MUSCLE STRENGTH, ATHLETIC PERFORMANCE, DANCING.

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INTRODUCTION

Modern dance is a complex body action that includes multidirectional technical movements with special properties requiring strength, power, flexibility, endurance, balance, and coordination with precision, artistry, and grace. Especially, muscular leg strength and power are considered as essential elements for successful dance performance as well as other motoric features (Koutedakis et al., 1997).

Dancers can perform 200 jumps per 1.5 hour with 50% of those jumps requiring a single leg landing. In addition, the dancers typically perform more jumps throughout the day during their rehearsals and performances (Liederbach et al., 2014). Within the complex features, dancers have a 90% lifetime injury incidence rate, with around 70% of all dance-related injuries occurring in the lower extremity (Ambegaonkar et al., 2016). It has been determined that insufficiency in strength (Angioi et al., 2009) and flexibility (Deighan, 2005) of the thigh muscles originating from the hip joint increases the risk of injury in dancers. It is also important to note that some studies (Angioi et al., 2009; Koutedakis, et al., 1997) confirmed that increased muscular strength is necessary to reduce injury incidence and severity in professional ballet and contemporary dancers. Therefore, the evaluation of muscles strength and balance are very important to help to increase performance, prevent and treat injuries and assist rehabilitation (Devan et al., 2004). The isokinetic dynamometer is the gold standard in this kind of evaluation and the test data's collected based on age, gender, and activity level (Stark, et al., 2011). Although there are many studies (Chmelar et al., 1988; Kushner et al., 1990; Westblad, Tsai-Felländer, & Johansson, 1995) concerning the evaluation of isokinetic muscle imbalance in classical ballet dancers, there are lack of studies concerning modern dancers and a lack of consensus on isokinetic muscle profiles (Agopyan et al., 2013; Koutedakis et al., 1997).

Another important aspect for a vital role in general health is proper blood circulation. The bloodstream continuously transports oxygen and nutrients to the brain, skin, and vital organs in the body. Red blood cells (RBC) are specialized to transport oxygen and carbon dioxide within the blood stream. Its shape gives each RBC a relatively large surface area to volume ratio that increases the rate of diffusion. RBC consists of molecules called hemoglobin (Hb). Hb is a complex protein molecule in red blood cells that contains an iron molecule and carries oxygen from the lungs to the body's tissues and returns carbon dioxide from the tissues back to the lungs. Anaemia is a condition in which the number of red blood cells and consequently their oxygen-carrying capacity is insufficient to meet the body's physiologic needs and Hb levels are used to diagnose anaemia at sea level ($g \cdot L^{-1}$) (WHO, 2011). According to the recommendation of the World Health Organization (WHO), the Hb cut-off points for the diagnoses of iron deficiency anemia of less than 110 $g \cdot L^{-1}$ for pregnant women, less than 120 $g \cdot L^{-1}$ for non-pregnant women and (15 years of age and above) and less than 130 $g \cdot L^{-1}$ for men (15 years of age and above) (WHO, 2011).

Anaemia, or low concentrations of Hb, adversely affect cognitive and motor development and cause fatigue and low productivity. It is believed that hematological parameters may also play a crucial role in predicting optimal physical performance (Schumacher et al., 2002). Therefore monitoring an athlete's immune function through hematological parameters has become an important part of competition preparation (Kakanis et al., 2010). These are also important risk factors for the health and development of women and children (Stevens et al., 2013). Whereas, female ballet dancers may be at risk for iron deficiency (Mahlamäki & Mahlamäki, 1988) due to inadequate dietary intake, growth, training volume and menstruation; and at risk for vitamin D deficiency (Constantini et al., 2010; Wolman et al., 2013) due to time spent training indoors and limited sun exposure. It is important to expose the risk factors in injuries in the context of the health and the careers of dancers. The risk of injury in lower extremities is higher in female dancers (Anand Prakash, 2017; Koutedakis, et al., 1997). However, to our knowledge, the relationship between hematological parameters and muscular strength remains unknown in dance literature. In the light of the existing studies, the main goals of this study were as follows: (*i*) to identify the isokinetic knee extensor and flexor muscles strength profiles (*ii*) to determine hematological profiles (*iii*) to describe the relationships between bilateral isokinetic knee extensor and flexor muscles strength and biochemical hematological parameters in female modern dancers.

MATERIALS AND METHODS

Participants

Twenty-one female modern dancers (mean age 24.24 ± 4.01 years) were participated voluntarily for the present study. Inclusion criteria included enrollment in a university level dance class and have at least 4 years' experience in modern dance. Exclusion criteria included a history of confounding medical problems or a current injury impacting on the execution of the dance task for the study. No participant was suffering from lower extremity musculoskeletal injury at the time of testing or during 6 months before testing. All dancers were right leg dominant. The participants were instructed to use the dominant leg as a lifted leg and left leg was the supporting leg in all participants. This was determined by asking the participants which leg they prefer to use in performance of technical movement in dance choreography.

Participants were divided into two groups based on Hb cut-off points (less than 120 g/l for non-pregnant women and 15 years of age and above) according to the WHO (WHO, 2011): Lower Hematologic (LHG; *n* = 9; 11.87 ± 0.1 $g \cdot L^{-1}$) and Higher Hematologic (HHG; *n* = 12; 13.69 ± 0.4 $g \cdot L^{-1}$) groups.

This research complied with the Helsinki Declaration and was approved by the Ethics Committee of Local University. Before enrolling in the investigation, the participants were fully informed of any risks and discomforts associated with the experiments before giving their informed written consent to participate.

Table 1. Descriptive for characteristics and training experience of less hematologic group (LHG; n = 9) and high hematologic group (HHG; n = 12) modern dancers.

	LHG	HHG			
Variables	Mean ± SD‡	Mean ± SD‡	*U*-test	z	*p*-value*
Age (year)	23.92±4.1	24.67±4.1	46	-0.572	0.567
Height (cm)	162.19±6.9	161.4±3.5	49.5	-0.320	0.749
Weight (kg)	53.11± 5.9	50.29±3.3	37	-1.209	0.227
BMI (kg/m^2)	19.32±1.4	20.18±1.8	38	-1.137	0.256
Experience (year)	10.25±4.4	10.11±6.1	47	-0.501	0.616
Total dance training hours per week	20.58±4.66	18.11±2.89	41.5	-1.208	0.227

BMI = Body mass index; ‡ SD, standard deviation; * *p*-value of less than 0.05 is considered statistically significant.

Experimental procedures

The study used a descriptive, cross-sectional study design and included two different sessions on separate days. The tests were performed at the same time (8.00 to 12.00 AM) over 1 week with a minimum interval of 48 hours between tests. Participants were instructed to attend for testing well rested, well nourished, and well hydrated. On the first visit informed consent was signed, anthropometric data (age, height and body mass), blood samples were collected, and dancers had a familiarization period on a trial practice of isokinetic muscle actions. On the second day, the main protocol was performed in the laboratory by the same experienced examiner. Each participant completed a 10-minute warm-up on a stationary cycle-ergometer (Monark Ergomedic 818E, Monark Exercise AB, Sweden) with the resistance set to 50 W and a pedaling cadence of 60 to 70 rpm before the initial isokinetic testing. Then all participants performed isokinetic testing on the dominant (right) and non-dominant (left) legs, randomly.

Anthropometric variables

Anthropometric measures included body mass (kg), and height (cm) without shoes and weight in light clothing. The measurements were performed according to the International Society for Advancement in Kinanthropometry (ISAK) (Marfell-Jones, Stewart, & de Ridder, 2011). Height was measured with a portable stadiometer accurate to 1 mm (Holtain Instruments Ltd, Crymych, United Kingdom), and weight with electronic scales accurate to 0.1 kg (Seca, Hamburg, Germany).

Venous blood sampling and analysis

Venous blood samples were drawn in the morning (8.00-9.00 AM), from an antecubital vein after a 10-min rest period in a sitting position. All blood samples of dancers were collected after 8-hour fast and at least 12 hours without training. None of the female dancers were pregnant or in menstruation cycle. For blood count, a 2.6 mL S-Monovette tube with K3EDTA (1.6 mg EDTA/mL blood-SARSTEDT AG & Co., Nümbrecht, Germany) was used. Venous blood samples were drawn to determine hematological blood variables, including number of erythrocytes/red blood cell (RBC-1012$\cdot L^{-1}$), hemoglobin concentration (Hb-g$\cdot L^{-1}$) and hematocrit value (Hct-%). The hematological parameters were analyzed in automated equipment (Pentra 120; ABX Diagnostics, Montpellier). Hematological analyses were conducted within 2 hours after taking the blood in the Biochemistry Laboratory, which has accreditation of the WHO certified laboratories.

LHG and HHG groups were divided based on Hb levels. Hb cut-off points (less than 120 g/l for non-pregnant women and 15 years of age and above) for the diagnoses of iron deficiency anemia were used according to the recommendation of WHO (WHO, 2011).

Isokinetic test protocol

Concentric isokinetic muscle torque during knee flexion and extension were performed in both legs with maximal voluntary. Peak torque [(PT)-N.m], peak torque % body weight [(PT%BW)-N.m.kg^{-1}], average peak torque [(AVGPT)-N.m] and total work [(TW)-J)] were measured for the knee extensor and flexor muscles of dominant and non-dominant limbs. All isokinetic contractions performed in a random order at a speed of 60ºs^{-1} (slow velocity), 180ºs^{-1} (medium velocity) and 300ºs^{-1} (high velocity) angular velocities, through a knee range of motion of 0° (flexed) to 90° (full extension) (Daneshjoo et al., 2013). The best values of each variable were used in the analysis of results.

All tests were performed with the use of Biodex System 3 Pro Multijoint System isokinetic dynamometer (Biodex Medical System, Inc, Shirley NY, USA; 1998) and controlled by the same qualified technician in accordance with the manufacturers' instructions (Biodex Pro Manual, Applications/Operations; Biodex Medical Systems, Inc. Shirley, NY, USA; 1998).

Seating adjustment were made with each participant positioned in 90º of hip flexion and 90º of the knee flexion in test chair. The dancers were positioned on the dynamometer seat with belts fastened across their trunk and pelvis to minimize body movements that could affect torque output. The contralateral leg was braced against the limb stabilization bar. The participant held the handles close to the chair to minimize the participation of the upper extremity. The lever arm was fixed 3 cm above the lateral malleolus and gravity correction was performed according to the manufacture's procedure. Before testing, three submaximal warm-up trials preceded 3 maximal muscle actions at each velocity in accordance with the Biodex User's Instructions.

The isokinetic measurements included 4 maximal repetitions of concentric knee extension and flexion recorded at both angular velocities 60º and 180°s^{-1}, and thirty repetitions of maximal extension/flexion at 300°s^{-1}. A 40-second rest period was allowed between tests at each velocity and a 5-minute break was allowed between tests for each limb. During the measurements, the participants were guided by standardized verbal instructions and encouragements.

Statistical analysis

Descriptive statistics (means and standard deviations) were used to summarize all data. Before nonparametric statistical procedures, the assumption of normality was verified using the Kolmogorov-Smirnov test and tests for normality of homogeneity of variance (Levene's test). The non-parametric Mann–Whitney U-test was used for pairwise comparisons between groups. The magnitude of difference between higher- and lower level hematologic groups was also expressed as Cohen effect sizes [ES]). In order to calculate η2 ES non-parametric tests Mann-Whitney-U were used (Fritz, Morris, & Richler, 2012). An ES of <0.1 was considered no effect, 0.1 to 0.3 small, 0.3 to 0.5 intermediate effect and > 0.5 as large ES (Fritz, Morris, & Richler, 2012). Spearmen correlation were used for statistical analysis. The level of significance was set at $p < 0.05$. Statistical analysis was performed using SPSS (version 21.0, Chicago, IL, USA) for Windows.

RESULTS

The groups' differences of the anthropometric and training characteristics are summarized in Table 1. There were no significant differences between groups in age, height, weight, dance experience or total dance training hours per week ($p > 0.05$). These results proved the homogeneity of groups. There were significant differences between groups in terms of RBC counts ($p \leq 0.05$), Hct, and Hb ($p \leq 0.001$) values and all the hematological values were lower in LHL dancers (Table 2). There were no significant differences between groups in terms of bilateral isokinetic knee flexor muscles strength ($p \geq 0.05$) in all angular velocities (Table 3). Significant differences ($p \leq 0.05$) were found between the LLH and HLH dancers in concentric contraction strength production at 300ºs^{-1} angular velocity in PT (+10.5%, $p < 0.05$, in a large ES of 0.849, $d = 3.211$), AVGPT (+9.9%, $p < 0.05$, in a large ES of 0.843, $d = 3.138$) and TW (+11.9%, $p < 0.05$, in a large ES of 0.865, $d = 3.44$) (300ºs^{-1}) of the left leg extensors muscles and all the values were higher in HLH dancers (Table 4). There was a significant negative correlation between TW (300ºs^{-1}) of left leg extensors muscles and RBC counts ($r = -0.479$, $p = 0.02$), Hct ($r = -0.437$, p = 0.04) and Hb ($r = -0.321$, $p = 0.02$).

Table 2. Descriptive for hematologic test parameters between less hematologic group (LHG; n = 9) and high hematologic group (HHG; n = 12) modern dancers.

Variables	LHG Mean ± SD‡	HHG Mean ± SD‡	*U*-test	z	*p*-Value*
RBC ($10^{12}\cdot L^{-1}$)	4.38 ± 0.4	4.63 ± 0.3	25	-2.062	0.039†
Hct (%)	35.44 ± 2.5	40.38 ± 1.4	1.00	-3.760	0.000††
Hb ($g\cdot L^{-1}$)	11.87 ± 0.1	13.69 ± 0.4	0.00	-3.839	0.000††

*RBC = red blood cell count; Hct = hematocrit; Hb = hemoglobin; ‡ SD = standard deviation; * Represents significant differences at † p ≤ 0.05, †† p ≤ 0.001.*

Table 3. Descriptive for isokinetic flexion test parameters between less hematologic group (LHG; n = 9) and high hematologic group (HHG; n = 12) modern dancers.

Isokinetic flexion parameters		LHG Mean ± SD		HHG Mean ± SD		Left leg			Right leg		
						U-test	z	*p*-value	*U*-test	z	*p*-value
	Velocity	Left leg	Right leg	Left leg	Right leg	49	-0.355	0.722	49	-0.355	0.722
PT	*60°/s*	47.8 ± 8.7	47.4 ± 11.3	48.9 ± 12.2	49.1 ± 13.1	43.5	-0.746	0.455	45	-0.640	0.522
(Nm)	*180°/s*	37.1 ± 9.4	35.5 ± 11.1	34.8 ± 8.3	37.6 ± 10.2	53.5	-0.036	0.972	46.5	-0.533	0.594
	300°/s	29.5 ± 7.9	27.9 ± 10.0	28.7 ± 6.1	29.4 ± 8.5	44	-0.711	0.477	45	-0.640	0.522
PT%BW	*60°/s*	91.5 ± 19.7	91.1 ± 25.9	97.8 ± 23.5	98.2 ± 25.6	48	-0.426	0.670	43	-0.782	0.434
(Nm /kg)	*180°/s*	70.7 ± 18.7	68.3 ± 23.3	69.4 ± 14.8	75.2 ± 19.9	49	-0.355	0.722	46.5	-0.533	0.594
	300°/s	56.2 ± 15.2	54.1 ± 21.6	57.3 ± 10.7	58.6 ± 16.4	45	-0.640	0.522	46	-0.569	0.570
AVGPT	*60°/s*	44.2 ± 8.5	43.4 ± 11.3	45.9 ± 12.2	44.9± 12.7	48	-0.426	0.670	49	-0.355	0.722
(*Nm)*	*180°/s*	33.8 ± 9.2	31.0 ± 11.7	32.3 ± 8.3	32.3 ± 11.3	48	-0.426	0.915	42	-0.853	0.570
	300°/s	22.1 ± 6.5	20.7 ± 7.7	21.3 ± 5.7	21.9 ± 6.9	43	-0.782	0.434	47	-0.497	0.619
TW	*60°/s*	261.2 ± 46.8	246.9 ± 78.5	270. 7 ± 70.3	259.9 ± 80.3	46	-0.569	0.570	51	-0.213	0.570
(J)	*180°/s*	195.5 ± 60.1	177.5 ± 73.4	187.4 ± 52.5	190.6 ± 75.7	52.5	-0.107	0.670	46	-0.569	0.670
	300°/s	764.1 ± 238.9	701.7 ± 281.2	708.8 ± 249.2	755.6 ± 266.9	49	-0.355	0.722	49	-0.355	0.722

PT, peak torque; PT%BW, peak torque percent body weight; AVGPT, average peak torque; TW, total work; SD, standard deviation.

Table 4. Descriptive for isokinetic extension test parameters between less hematologic group (LHG; n = 9) and high hematologic group (HHG; n = 12) modern dancers.

Isokinetic extension parameters		LHG Mean ± SD		HHG Mean ± SD		Left leg			Right leg		
						U-test	z	*p*-value	*U*-test	z	*p*-value
	Velocity	Left leg	Right leg	Left leg	Right leg						
PT	*60°/s*	112.2 ± 10.9	115.2 ± 18.6	113.1 ± 14.3	115.8 ± 17.8	51	-0.213	0.831	50.5	-0.249	0.804
(Nm)	*180 °/s*	78.8 ± 9.4	77.5 ± 12.9	81.7 ± 10.0	82.3 ± 16.7	46	-0.569	0.570	42	-0.853	0.394
	300 °/s	56.9 ± 7.2	59.1 ± 7.4	62.9 ± 6.4	62.2 ± 9.3	53.5	-0.036	0.040†	26	-1.991	0.414
PT%BW	*60°/s*	214.7 ± 33.5	220.2 ± 41.8	226.1± 25.1	231.5 ± 32.4	47	-0.497	0.619	51	-0.213	0.862
(Nm / kg)	*180 °/s*	156.2 ± 25.3	156.8 ± 31.9	157.7 ± 18.4	155.2 ± 27.5	51	-0.213	0.831	48	-0.426	0.670
	300 °/s	113.9 ± 15.1	118.4 ± 15.9	120.0 ± 16.8	118.6± 19.4	49	-0.355	0.356	41	-0.924	0.776
AVGPT	*60°/s*	102.5 ± 9.6	103.0 ± 21.6	103.6 ± 15.9	104.6 ± 15.7	53	-0.071	0.943	54	0.000	1.00
(*Nm)*	*180 °/s*	73.1 ± 10.2	68.1 ± 17.6	75.5 ± 11.7	72.3 ± 17.0	47	-0.497	0.619	34	-0.421	0.722
	300 °/s	42.0 ± 3.9	43.8 ± 4.7	46.6 ± 4.8	46.3 ± 6.4	52.5	-0.107	0.013†	19	-2.487	0.455
TW	*60°/s*	552.2 ± 53.9	551.8 ± 116.8	570.3 ± 92.3	553.5 ± 91.8	52	-0.142	0.887	51	-0.213	0.831
(J)	*180 °/s*	385.6 ± 107.6	393.8 ± 96.7	432.3 ± 67.2	403.2 ± 93.8	40	-0.995	0.320	49	-0.355	0.722
	300 °/s	1616.3 ± 202.7	1673.6± 192.7	1808.9 ± 185.2	1720.1 ± 257.2	48	-0.426	0.033†	24	-2.132	0.619

*PT, peak torque; PT%BW, peak torque percent body weight; AVGPT, average peak torque; TW, total work; SD, standard deviation; * Represents significant differences at † p ≤ 0.05.*

DISCUSSION

The primary aim of this study was to describe the relationships between bilateral isokinetic knee extensor and flexor muscles strength, and biochemical hematological parameters in female modern dancers. In addition, the second aim of this study was to determine the hematological and isokinetic thigh muscles strength profiles of female modern dancers. To our knowledge, this is the first scientific report to examine the relationships between bilateral isokinetic knee extensor and flexor muscles strength and biochemical hematological parameters in female modern dancers. To help further interpret the results we have not solely relied on p values but have also reported the effect sizes.

Measurement of muscle strength is an important concern to achieve muscular performance and prevention for injury in dancers (Agopyan et al., 2013). In addition, acute and chronic exercise training produce different effects on hematological parameters and most of the hematological studies in literature have focused in different sport disciplines in athletic population (Ahmadi et al., 2010; Chiu et al., 2015; Kokubo et al., 2016; Petersen, et al., 2006). It has been reported that anemia is one of the deteriorative problems in athletes especially in females (Yasui, et al., 2015). The prevalence of anemia has been in the range of approximately 15-38% on professional or top-level female athletes (Yasui et al., 2015). However, reports on anemia in modern dancers are still limited. Furthermore, today the relationship between hematological parameters and muscular strength remains unknown in dance literature. Thus, we cannot compare one to one base of our findings with other studies.

The main findings of this study was indicated that the ability of the HLH modern dancers to achieve significantly greater isokinetic knee extensors muscles strength in PT (+10.5%; in a large ES of 0.849), AVGPT (+9.9%; n a large ES of 0.843) and TW (+11.9%; in a large ES of 0.865) of the non-dominant leg at high angular velocities (at 300ºs^{-1}). with a large effect size. However, despite differences in hematological level, female modern dancers display similar PT (60º, 180ºs^{-1}). PT%BW (60º, 180º, 300ºs^{-1}), TW (60º, 180ºs^{-1}) and AVGPT (60º, 180ºs^{-1}) values of flexor and extensor muscle groups of the knee joint in some angular velocities. There was also a significant negative correlation between TW (300ºs^{-1}) of left leg extensor muscles and RBC counts, Hct and Hb.

Hematological analyses revealed that all of the LHG dancers in the current study were under normal clinical ranges. LHG dancers had Hb values (11.87 ± 0.1 g·dl^{-1}) in mild anemia level (11.0-11.9 g·dl^{-1}), that is recommended by the WHO (WHO, 2011). This finding suggests that the lower hematological dancers were not subjected to an appropriate level of training intensity and duration while developing the technical, tactical, and physical skills to dancing well.

It is observed that the results of hematological values (especially with LLH dancers) of present study (Table 2) are generally lower than those of the previous studies (Ahmadi et al., 2010; Kokubo et al., 2016; Petersen et al., 2006) performed in female's athletes. Our results regarding hematological variables of LLD (Table 2) are slightly lower than the results obtained in Kokubo et al. (2016) for iron deficient rhythmic gymnasts (RBC value of 4.31 ± 3.4 x106/µl, Hct of 38.4 ± 3.1%, and a Hb of 12.6 ± 1.1 g·dl^{-1}). On the other hand, the hematological mean values of the HLH dancers group were higher than the values reported Kokubo et al. (2016) The mean value of preseason Hct (42.2 ± 1.9%) and Hb levels (132.2 ± 7.2 g/L – in g·dl^{-1} 13.22) which has been reported by Petersen et al. (2006) for female swimmers and drivers were higher than our both of group dancers. Similarly, the results of Ahmadi et al. (2010) conducting research on female ball-team (basketball, volleyball and handball players) athletes, reported higher hematological values (RBC value of 4.9 ± 0.3 x106/µl, Hct of 41.5 ± 2.6%, and a Hb of 13.6 ± 1.1 g·dl^{-1}) compared present study.

Because iron is involved in many essential functions such as oxygen storage and transport, energy production and metabolism, immune and central nervous system function, the low level hematological dancers in the current study could be candidates for high-iron diet interventions and, in some individual cases, supplementation (Gibson, et al., 2011).

Modern dance is predominantly an intermittent type of exercise. For optimal performance, the dancers must be also physically fit. Therefore, in order to prevent them from injury it is important for dancers to optimize exercise performance (Angioi et al., 2009). From this point of view, another essential result of our study is that there were a strong, negative correlation between TW (300ºs^{-1}) of left leg extensor muscles and RBC count, Hct and Hb values indicating that the dancers with weak muscle strength generate lower muscular endurance. The hematologic parameters can be crucial for predicting optimal physical performance (Chiu et al., 2015; Ostojic, & Ahmetovic, 2009). In the present study, this interaction was occurred especially isokinetic strength production performances at 300ºs^{-1} angular velocities, which is a muscular endurance indicator. TW at 300ºs^{-1} angular velocity is similar to muscle contraction speed during sports activities and it is a reliable measure for muscle performance like PT. It is a more accurate measure of muscle endurance capacity (Agopyan et al., 2013). The importance of negative relationship between hematologic parameters and muscular strength production may be considerably more significant because relatively weak knee flexor and extensor muscles can be associated with low back and lower extremity injuries in dancers (Koutedakis et al., 1997). We recommend testing strength developments periodically and implementing special strength training in order to lower injury risk especially for dancers who have low level strength and low level hematological values. The results of our study are in line with the results of other studies (Reilly, & Ekblom, 2005) which has been provided that in sports activities the musculoskeletal, nervous, immune and metabolic systems might be reflected in changes in the biochemical and hematologic parameters. It is well known that limited Hb production and concentration with reeducated oxygen transport capacity and thus decreased maximal oxygen uptake (Shaskey, & Green, 2000). Inadequate iron storage has negatively affected aerobic capacity, strength, and muscular fatigue, and has delayed skeletal muscle recovery (Pasricha, et al., 2014). The results of our research support the view, which has been indicated that low-level Hb negatively affect skeletal motor development and this situation cause low productivity (Stevens et al., 2013).

The stability of hematologic status is one of the key determinants of optimal exercise performance, particularly in endurance sports such as soccer and long-distance runners (Chiu et al., 2015; Gibson et al., 2011). The decrease in Hb and Hct is a sign of physical exertion and heavy participation (Malcovati, Pascutto, & Cazzola, 2003). These reductions of hematologic parameters mainly occur due to exercise-induced plasma volume expansion, which sets in within a few days of exercise training (Convertino, 1991). Dance is inherently a bilateral (Agopyan et al., 2013). It is assumed that dancers participating in activities, which demand symmetrical motor tasks, have similar strength in the two lower extremities. However, the left leg extension muscles [quadriceps femoris (QF)] of high hematological dancers have significantly greater strength (PT, AVGPT and TW) than the LHG dancers. The demographic characteristics and training levels of dancers are the same, it has been speculated that these differences may be due to nutritional status and biochemical parameters may be affected negatively in this situation. In the present study, all of the dancers were right side dominant as a lifted leg and left side non-dominant as a supported leg. The supported leg is the leg that is actively used in the pushing during the take-off phase of jumps/leaps movements such as jumping from the ground and while standing on one leg in the balance or pivot elements. The QF muscles are very effective in these kinds of movements during the take-off phase of jumps/leaps or while supporting on one leg. The lower level of hemoglobin can show more of the effects of muscles, especially those that perform movements to produce more power. Hematologic parameters are influenced by several factors like training, age, sex, ethnicity, nutrition and altitude (Ostojic, & Ahmetovic, 2009). Any one or all of these factors can have a positive or negative influence on RBC count, Hct, and Hb (Ostojic, & Ahmetovic, 2009). However, these variables have not been examined since it is not included in the purposes of the research. We recommend that more attention should be paid to the nutrient intake of female modern dancers.

Another important detail revealed in our research that the PT strength values ($60^{o}s^{-1}$) of LHG and HHG dancers are lower than the QF and hamstrings (H) muscles values of the modern dancers (QF:133 N.m; H:68 N.m), dance students (QF:126 N.m; H:64 N.m) classical ballet dancers (QF:118 N.m; H:59 N.m) and elite athletes (QF:160 to 212 N.m; H:79 to 110 N.m) in the study of Brinson and Dick (1996). This difference may be explained by adaptations caused by different training programs or by differences in experience levels. We suggest supplementary strength training focusing on increasing muscle strength in lower extremities of our dancers because the dancers with low strength values may be at risk of injury. Koutedakis et al. (1997) compared female modern dancers with male ballet dancers, and the authors suggested that lower thigh-output power correlated with increased lower extremity injuries, but not back injuries. Angioi et al. (2009) report that contemporary dances are submitted to a high daily workload of rehearsals and classes, especially when upcoming performances are approaching. Especially lower H and QF muscle torques have been found to be associated with more days off due to lower-body injuries in modern dancers (Koutedakis, 1997). In this respect, the results we have achieved are important. It is understood that dancers, especially those with low hematological values and low isokinetic strength values, should pay more attention.

We acknowledge that there are some limitations of our study. This is a pilot study due to the small number of participants and a larger study would be needed to verify any results they have obtained. Secondly, only female modern dancers were enrolled in our study, which may account for sex differences in regard to hematologic data. Study results demonstrate only the profiles of front and back thigh muscles of female modern dancers.

The ferritin, iron, transferrin, transferrin saturation levels should be evaluated to determine iron deficiency. Nonetheless, our results provide a basis that future researches work may extend on, assist in guiding dancers, educators and clinicians, and contribute to the identification of factors that promote high performance in modern dance.

The results of this study reveal several strategies that would benefit dance educators. Low hematological variables may impair isokinetic muscle performance in university level female modern dancers. The difference in isokinetic strength production variables of the low and higher level hematological university levels of the female dancers should be considered during training. The findings indicate that dance educators should developed particularly, muscular strength endurance parameters to the low-level hematologic dancers.

CONCLUSION

The current study is the first to provide a detailed the relationship isokinetic and hematological profiles of female modern dancers. The non-dominant extension muscles of high hematological dancers have significantly greater isokinetic strength (PT, AVGPT and TW) than the LLH dancers. The low-level hematological parameters had impact on torque production (PT, AVGPT and TW) of extensors muscles in non-dominant (supporting) leg during isokinetic muscle strength endurance in university level female modern dancers. The present study demonstrates evidence that extensor and flexor muscles of the knee are not similarly affected by hematological variables level. Isokinetic strength endurance has been associated with low-level hematological variables. Significant negative correlations between isokinetic strength production (at $300^{o}s^{-1}$ angular velocity) and hematologic variables have been identified in female modern dancers. It can be recommended that testing hematological level periodically and extra supplementation of nutrients helped to offset the deficits of hematological level. It is important to maintain balanced nutrition and gain appropriate education programs regularly. In addition to periodically testing the muscular strength development, modern dancers should strive to improve their knee strength in order to potentially prevent injuries by special strength training. Further studies are needed to determine and focus on topics of muscular and hematological profiles for male dancers.

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