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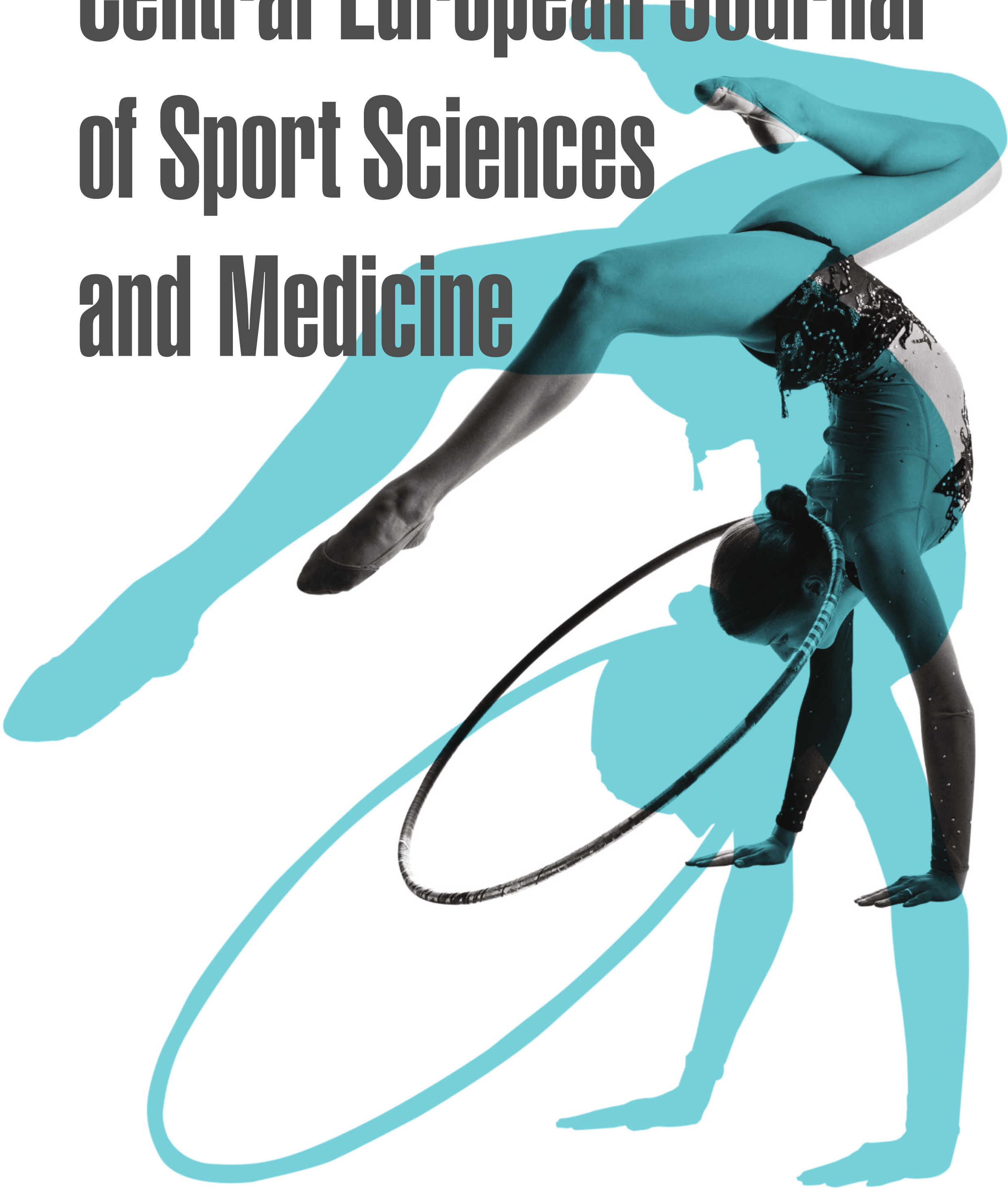

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MODELING THE TOTAL ENERGY COSTS OF RESISTANCE EXERCISE: A WORK IN PROGRESS

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Abstract. We present an aerobic and anaerobic, exercise and recovery energy cost model of intermittent energy costs utilizing task (work, Joules) as opposed to rate (per minute) measurements. Low to moderate intensity steady state exercise energy costs are typically portrayed as the volumetric rate at which oxygen is consumed (VO_2 L min^{-1}), where a proportionate upward climbing linear relationship is profiled with an increasing power output; add to this the concept of the anaerobic threshold and energy costs increase with more intense aerobic exercise in disproportion to VO_2 L min^{-1} measurements. As a per task function, intermittent work and recovery bouts contain a combined estimate of total costs, that is as kJ or kcal (not kJ·min^{-1} or kcal·min^{-1}). Adopting this approach to describe single and multiple sets of resistance training, the model that emerges for intermittent resistance exercise portrays linearity between equivalent work and total energy costs that differs proportionately among conditions – "continuous" muscular endurance vs. intermittent higher load strength work, moderately paced vs. slower and faster conditions, smaller vs. larger working muscle masses and failure (fatigue) vs. non-failure states. Moreover, per kcal (or kJ) of total energy costs, work (J) is more inefficient with a greater load and lower repetition number as opposed to lower resistance with an increased number of repetitions. The concept of energy costs rising disproportionately with increased or prolonged work does not appear to apply to resistance exercise.

Key words: intermittent exercise, weight lifting, oxygen uptake

Cost per task (not per minute)

Validation has not been provided for the almost universal use of steady state per minute exercise oxygen uptake measurements (e.g., VO_2 l·min^{-1}) in the estimation of the energy costs of non-steady state exercise (Scott, Reis, 2014). An example of this practice suggests that a modified per minute oxygen uptake measure taken exclusively in recovery may better estimate resistance exercise energy costs (Vezina, Ananian, Campbell, Meckes, Ainsworth, 2014). Again, there appears to be no precedent in eliminating exercise energy costs when estimating overall exercise and recovery energy costs. Indeed, this practice instead reveals the limitations of steady state per minute measurements. We promote an estimate of both the exercise and recovery energy costs of intermittent exercise along with their aerobic and anaerobic metabolic components as obligatory to the overall total energy cost – resistance exercise and recovery costs should be summed not averaged.

We have adopted a per task work model that allows for the collection of all energy cost components – aerobic and anaerobic, exercise and recovery – as kJ or kcal (not $kJ \cdot min^{-1}$ or $kcal \cdot min^{-1}$) for resistance exercise. Intermittent resistance work (J) was electronically recorded as the product of vertical bar movement (on a Smith machine) and weight lifted (with a coefficient of variation of 0.25% between reps and 0.75% between sets) (inertia was not accounted for) (Scott, Croteau, Ravlo, 2009).

Contrary to the concept of an anaerobic threshold as applied to higher intensity aerobic-type exercise, our model has yet to reveal any disproportionate increase in energy costs at higher work volumes (Scott, Reis, 2014). Total energy costs instead rise linearly with work and as the conditions of lifting change – with a greater number of higher load intermittent sets, with slower and faster lifting speeds, with the use of larger muscle masses and when lifting to fatigue – these costs increase in linear proportion to work (Figure 1).

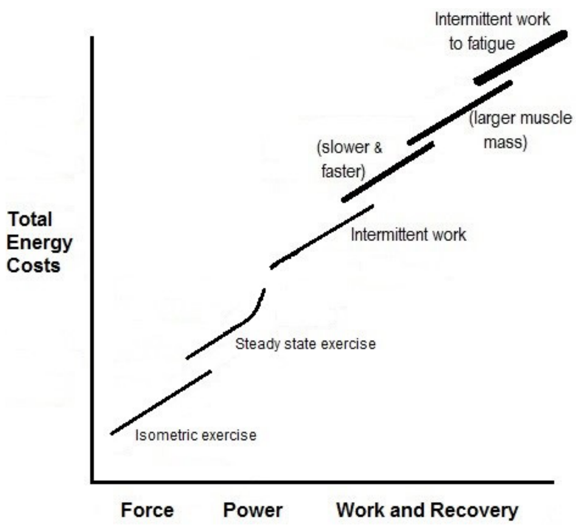

Figure 1 The total energy costs (aerobic and anaerobic, exercise and recovery) of force, power, and work bouts are hypothetically depicted. Isometric exercise reveals the lowest energy cost. With steady state power, energy costs increase disproportionately after the anaerobic threshold is reached. Work and recovery are depicted as rising in linear and proportional fashion under a variety of conditions: with greater load intermittent bouts, with slower and faster lifting speeds, and with the use of an increased muscle mass; each has a greater total cost than equivalent work performed at a moderate pace (parentheses indicate the interchangeability of conditions). Lifting to muscular failure increases total energy costs further, likewise in a proportional linear manner as compared to non-failure (not an exact scale, increased variability is denoted via increased line thickness).

Movement

Comparison of three Tabata-type calisthenic squat routines revealed that isometric exercise conditions provide the lowest total energy costs as compared to isotonic and plyometric conditions (Scott, Nelso, Martin, Ligotti, 2015).

Based on force-velocity relationships however, the greatest force skeletal muscle can apply is under isometric conditions. From such perspectives isometric exercises represent an ideal means of strength and conditioning training, but they do not maximize energy costs. Physical movement appears integral to maximizing the caloric costs of exercise, and that likely includes resistance exercise.

Intermittent Conditions

Using thermodynamic considerations regarding metabolism as opposed to combustion, the oxidation of glucose has been suggested at 5.0 kcal (21.1 kJ) per liter of oxygen consumed; with fat and lactate as fuels the conversion in terms of one liter of oxygen consumed is 4.7 kcal (19.6 kJ) (Scott, 2014). Put another way, for every kcal of energy cost, 0.20 liters of oxygen are consumed when using glucose as a fuel (1 kcal = 0.20 LO_2); with fat and lactate oxidation, for every 1 kcal of energy cost, 0.21 liters of oxygen are consumed (1 kcal = 0.21 LO_2). Thus, if recovery costs 20 kcal (84 kJ) then with glucose as a fuel, 4.0 liters of oxygen are consumed; with fat and lactate oxidation, 4.3 liters of oxygen are consumed.

Because fuel selection is dependent on exercise “intensity” it appears likely that higher intensity intermittent exercise periods would consist primarily of glucose oxidation (as well as use of the high energy phosphates – ATP and PCr). During intermittent recovery periods, when muscle is not contracting (i.e., zero “intensity”), lactate and fats are the likely predominate fuel source. We view 2 sets or more of resistance exercise as having 2 or more respective recovery periods that are all summed to provide a single recovery energy cost estimate; the term ‘excess post-exercise oxygen consumption’ (EPOC) identifies the last recovery period by name only (Scott, 2012a).

In reference to substrate utilization, a larger *quantitative* (proportional) difference would exist in the oxygen-related costs between steady state exercise (power output) consisting of a single recovery period and equivalent work performed under intermittent conditions (Figure 1). A *qualitative* difference is further apparent between low to moderate intensity steady state and higher intensity intermittent conditions, with the potential for the latter to exhibit greater body composition changes (fat loss) (Boutcher, 2011; Hunter, Weinsier, Bamman, Larson, 1998).

Total energy cost components

Resistance and aerobic exercise are different and highly specific in terms of physiological responses (Knuttgen, 2007). Indeed, under typical resistance training loads, working skeletal muscle does not appear to receive a steady supply of oxygenated blood (Tamaki, Uchiyama, Tamura, Nakano, 1994). In fact for intermittent non-steady state weight lifting, the aerobic-anaerobic exercise-recovery energy cost of work per set is quite opposite that of the steady state model: 1) the volume of oxygen consumed during the actual weight lifting (exercise) period (L O_2) represents the lowest contribution to overall energy costs, 2) recovery oxygen uptake (L O_2) often represents the largest energy cost contribution (representing, in part, the so-called alactic component of ATP and phosphocreatine (PC) utilization and re-synthesis) along with, 3) anaerobic (glycolytic) costs that are often quite extensive as portrayed by blood lactate levels that rise predictably with work (Scott, Croteau, Ravlo, 2009; Scott, Leighton, Ahearn, McManus, 2011; Scott, 2012a). With low to moderate intensity steady rate power output: 1) as a per minute function, exercise oxygen uptake (VO_2 $l \cdot min^{-1}$) always represents the largest contributor to overall costs, 2) oxygen uptake in recovery (EPOC) may or may not contribute significantly to overall costs and, 3) anaerobic costs need not be considered.

Unfortunately, at this point in time, no universal consensus exists regarding how anaerobic (glycolytic) energy costs should be quantified. From such a vantage point and the possibility that glycolytic costs may not contribute significantly to overall energy costs, it appears likely that the energy expenditure focus for resistance exercise will continue with oxygen-only measurements. Recent evidence however suggests that blood lactate measurements can in fact provide a reasonable marker of an anaerobic glycolytic energy cost component, that is under the conditions of work and not power output (Buitrago, Wirtz, Flenker, Kleinoder, 2014; Gorostiaga et al. 2014).

Inefficiency

Further information is found when examining the ratio of the amount of work performed along with the associated aerobic and anaerobic, exercise and recovery costs in an attempt to recognize the work-to-cost ratio in regard to the overall work performed. For single sets of submaximal lifts, where muscular failure or fatigue was not reached, it is apparent that the work-to-cost ratio reaches a plateau with increasing repetitions (Figure 2). A similar relationship also was found when lifting to muscular failure (Figure 3). The anaerobic threshold concept of disproportionately increasing energy costs is not portrayed by our cost per task analysis. Indeed the opposite appears, efficiency improves as more work is completed. This unique relationship appears to be the result of an increasing aerobic and anaerobic exercise energy cost component with work, yet with recovery and/or EPOC costs, linearity with work is not straight-forward (Scott, Croteau, Ravlo, 2009; Scott, Leighton, Ahearn, McManus, 2011; Scott, Leary, TenBraak, 2011).

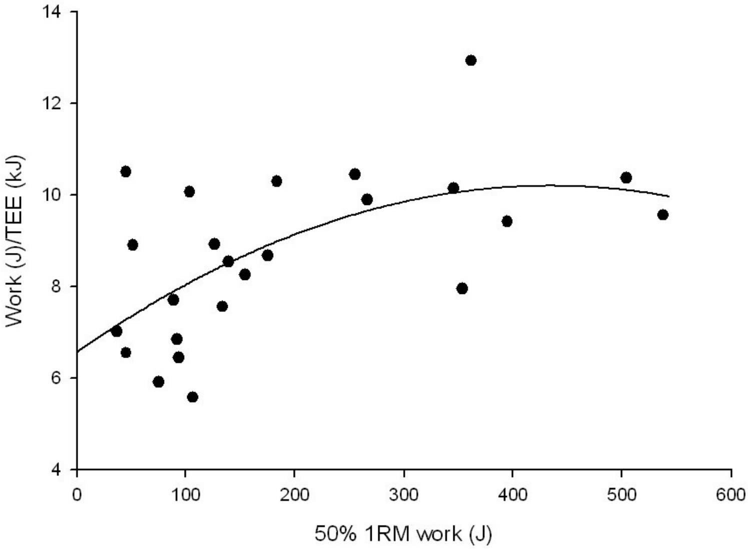

Figure 2. The work (J) to total energy costs (kJ) ratio is shown for submaximal lifting (50% 1-RM) of 1-set of the bench press exercise, muscular failure (or fatigue) was not an endpoint (Scott, Croteau, Ravlo, 2009). The data points represent 7, 14 and 21 repetitions. A quadratic equation was used to provide a line of best fit (SigmaPlot v.12). Efficiency appears to improve as the amount of work increases; as part of the sum of aerobic and anaerobic energy costs, EPOC appears to plateau as resistance work increases.

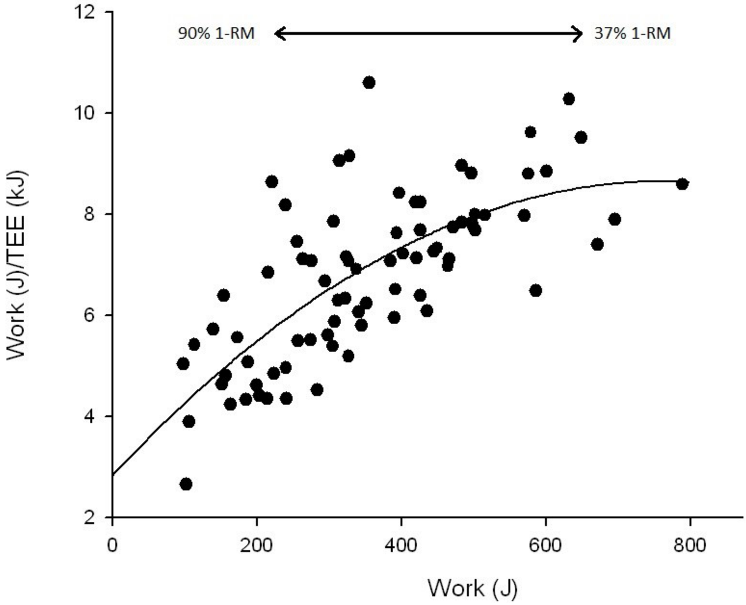

Figure 3. The work (J) to total energy expenditure (kJ) ratio is shown for 1-set of bench press lifting to muscular failure at: 90%, 80%, 70%, 56%, 46% and 37% of a one repetition maximum load (1-RM) (Scott, Leighton, Ahearn, McManus, 2011). A quadratic equation was used to provide the line of best fit (SigmaPlot v.12). At the lowest load (37% 1-RM), as with submaximal lifts (Figure 2), greater work is completed in relation to a lower total energy cost - efficiency appears to improve. An improving efficiency with increased work appears to be the result of an EPOC (and/or recovery) volume that plateaus as work increases (for single sets and double sets, respectively) (Scott, Leary, TenBraak, 2011).

When single lifts were performed to failure it was the largest load – at 90% of a 1-RM – that had the least amount of work completed per kcal of energy cost: 1 kcal per 21 Joules of work (Table 1; Figure 3). Compare this to the muscular endurance-type workload (37% 1-RM) where for every kcal utilized, 34 Joules of work were completed. The same pattern was seen when lifting to failure with consecutive sets (Scott, Leighton, Ahearn, McManus, 2011). The concept of an improved efficiency may represent a real difference between intermittent work bouts and steady state power output (see Woledge, 1998).

Table 1. Inefficiency of the Bench Press: 1 set to failure

% 1-RM	Reps	Total Cost (kcal)	Work (J)	Joules per kcal ($J \cdot kcal^{-1}$)
37	36	15	514	34
46	25	14	439	31
56	20	14	426	30
70	12	12	342	28
80	8	11	274	25
90	4	8	167	21

Source: Scott, Leighton, Ahearn, McManus (2011).

Greater work costs proportionately more as compared to less, regardless of the load (Figure 1). However, utilizing the concept of inefficiency (Table 1), the hypothetical completion of 3 sets at a high load of 90% of a one repetition maximum (1-RM) – 12 total repetitions (501 J) at a cost of 24 kcal – would be required to closely match the work of 1 set at 37% 1-RM (low load) consisting of 36 repetitions (514 J), with a 9 kcal increase in total costs for the former. Per volume of work (J), the use of a higher load in association with a greater number of intermittent exercise *and* recovery periods is suggested to increase overall or total energy costs.

Muscle mass and work

Several single-set resistance exercises were compared in terms of the overall work completed and the associated total energy costs (Scott, Luchini, Knausenberger, Steitz, 2014). It needs to be kept in mind that the load and repetition combinations for each lift varied tremendously; there also may be a gender effect as well. Even so, at equivalent submaximal work (J), the total energy cost was lowest for the flat and incline chest press (smallest muscle mass), larger for the squat (moderate muscle mass) and greatest for the deadlift (largest muscle mass); total energy costs rose linearly with work for each lift.

While certainly requiring more research, we currently portray the energy costs for the completion of a given amount of work to be proportionately larger the greater the amount of recruited muscle mass (Figure 1).

Lifting speed

The effects of lifting speed on total energy costs also has undergone partial examination. Utilizing the bench press exercise at 70% 1-RM where 3 sets of 5 repetitions were completed (15 overall reps) at two different lifting speeds – slow (5 seconds per rep) and moderate (3 seconds per rep) - two similar workloads were compared (Scott, 2012b). With the lifting speed slowed down from 15 seconds per set to 25 seconds per set, total costs increased by 6 kcal – inefficiency drops from 33 to 23 Joules of work per kcal.

We have not yet completed an energy cost and work study at rapid lifting speeds but, at faster lifting speeds inertia almost certainly plays a greater role and overall costs per task should increase as compared to moderate lifting speeds. Estimating work as the product of load, repetition, set number, and time to complete repetitions, it has been shown that explosive muscular contractions can indeed increase the energy costs of resistance exercise (Mazzetti, Douglass, Yocum, Harber, 2007).

Lifting to failure

Based on a retrospective investigation, lifting a weight to failure for one set promotes the largest total energy cost, also rising linearly and in parallel proportion as compared with submaximal equivalent work (Figure 1) (Scott, Earnest, 2011). Again, our model does not indicate the presence of an anaerobic threshold description for resistance exercise, when “extra” aerobic costs continue to rise disproportionately. With weight lifting (as opposed to steady state exercise), where blood flow to muscle is likely occluded or arrested, the “extra” total costs promoted by muscular failure appear fixed, regardless of the amount of work completed. However, at the lowest loads and as more work is completed, efficiency appears to improve, both with and without muscle failure (Figures 2 and 3).

Limitations

Perhaps the greatest limitation to the study of resistance exercise is in the quantification of work. On the one hand tradition dictates some compendium of a percentage of a repetition maximum (% RM), weight lifted, repetition number and sets completed. On the other hand the unit of measurement for work is designated as the Joule – a product of force, distance and inertia. While power output (Watts) is well understood, Joules of work is a foreign language to many involved with resistance training, including exercise scientists, though it has been shown to be the most valid method of quantifying resistance training "volume" (McBride et al., 2009). The concept of EPOC versus recovery oxygen uptake also presents as a limitation. Four sets of a specific resistance exercise for example, would consist of 3 recovery periods and 1 EPOC. Such representation is suggestive of recovery being separate from EPOC when in fact they both represent non-exercise phases (i.e., 4 overall recovery periods with EPOC representing the last and longest of those periods). The total exercise energy cost model presented has been designed to examine resistant exercise 1 set at a time and may not be descriptive of a complete resistance training workout.

Practical implications and conclusions

Our per task Work model (J) represented by a total energy cost estimate (kJ) – aerobic and anaerobic, exercise and recovery - provides an alternative method of analysis as compared to traditional steady state per minute measures. At present, for intermittent resistance exercise with independent recovery periods, we propose linear and proportional increases with total energy costs and work. Moreover, per kcal of total energy costs, work is most inefficient with a greater load and lower repetition number as opposed to lower resistance with an increased number of repetitions.

The energy cost – work relationships presently depicted serve as a blueprint or framework for the design of exercise-related weight loss programs where the absolute numerical cost of the exercise may not be known, but the relative description of the exercise format can suggest lower and higher total energy cost profiles. Brief, intermittent, high-load, resistance exercises with recovery periods, utilizing large muscle masses, performed slowly or quickly, to failure, would hypothetically promote the greatest total energy cost for a given volume of work.

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MODELLING MUSCLE FORCE DISTRIBUTIONS DURING THE FRONT AND BACK SQUAT IN TRAINED LIFTERS

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Abstract. The barbell squat is a fundamental strength and conditioning exercise, with two principal variants; back and front. Whilst previous studies have examined the mechanical differences of the front and back squat, there is no information comparing the distributions of muscle forces between these variants. This study aimed to compare estimated forces developed by the primary skeletal muscles used in the front and back squat. Twenty-five male participants were recruited with 6.24 ±2.21 years of experience in squat lifting and 1 repetition maximum values of 127.5 ±18.8 and 90.6 ±14.4 kg for the back and front squat lifts. Participants completed both back and front squats at 70% of their front squat 1 repetition maximum. Muscle forces were determined during dynamic situations using motion capture data, in addition to sagittal plane kinematics. Differences between squat conditions were examined using a multivariate analysis of variance. The kinematic analysis showed that the back squat was associated with significantly ($p < 0.05$) greater flexion of the trunk. Examination of muscles forces indicated that erector spinae forces were also significantly ($p < 0.05$) larger in the back squat. No significant differences were identified for skeletal muscle forces elsewhere ($p > 0.05$). Our results indicate that neither the front nor back squat provides any marked difference in muscle force production, aside from that isolated to the lower back. These findings lead the conclusion that neither the front nor back squat conditions confer any additional benefits over the other in terms of the skeletal muscle force output.

Key words: Biomechanics, resistance training, weight lifting

Introduction

Barbell squats are a principal lift in fundamental strength and conditioning (Clark, Lambert, Hunter, 2012). The purpose of the squat is to train and strengthen the muscles associated with the hip and knee joints (Wilk et al., 1996). The squat is representative of a closed kinetic movement and has been shown to closely represent a number athletic and everyday motions (Escamilla et al., 1998; Wilk et al., 1996). It is traditionally represented as a central exercise in training routines designed to augment athletic performance and to enhance quality of life (Escamilla, 2001). The squat has two principal variants; back and the front squat lifts. Although both squat conditions are mechanically similar, variations may exist in terms of technique and muscular involvement (Russell, Phillips, 1989).

During the back squat, when the high bar position is utilized the lifter positions the bar superior aspect of the trapezius below the C7 spinous process (Baechle, Earle, 2008; Russell, Phillips, 1989). The back squat is accomplished by flexing the hip and knee joints until the thigh segment is parallel to the ground (Escamilla, 2001). Having achieved the required depth, the lifter then extends the hip and knee joints until the original standing position is attained. The front squat requires the lifter to place the barbell in an anterior position aligned with the clavicular ridge. When the clean grip is adopted the elbows are flexed and the shoulders are and internally rotated. This allows the upper arm segments to be positioned parallel to the ground (Baechle, Earle, 2008; Gullett, Tillman, Gutierrez, Chow, 2009). The phasic aspects of the descent and ascent of the front squat are identical to those in the back squat. Typically, the back squat is executed with the trunk in a more flexed position in relation to the front squat. This relates to the more posterior position of the barbell, whereby distal aspect of the trunk must be projected anteriorly in order to maintain balance during the lift (Baechle, Earle, 2008, Gullett et al., 2009).

There is an emerging body of research relating to the biomechanical properties of both squat variants. Russell, Phillips (1989) compared kinematics and knee extensor torque during the front and back squat lifts. No difference in knee torque was found between different squat conditions although the back squat increased trunk flexion which was attributed to the posterior position of the bar. It should be noted however that this study utilized an incorrect technique to determine the distal end of the trunk, which may have influenced the resultant trunk inclination. Diggin et al. (2011) examined the differences in trunk and lower limb kinematics between the front and back squat. Their findings confirmed previous findings that the back squat was associated with significantly greater trunk lean compared to the front squat. Stuart, Meglan, Lutz, Growney, An (1996) examined tibiofemoral joint forces and muscle activity during the front and back squat conditions using a low mass 50 lb barbell. They showed that neither tibiofemoral forces nor muscle activation differed significantly as a function of the different squat techniques. Similarly Gullett et al. (2009) examined tibiofemoral joint kinetics and activation of the quadriceps, hamstring and erector spinae muscles when performing the front and back squat lifts. They showed that the back squat resulted in larger tibiofemoral compressive forces and knee extensor moments than the front squat, although no differences in muscle activation were observed.

Whilst a comprehensive overview of the biomechanics of front and back squats has now emerged, there has yet to be a comparative examination of the muscles forces associated with the two squatting modalities, notably with regard to skeletal muscle force distributions. A lack of suitable measurement tools, used to determine dynamic muscle forces, is a key limitation.

Recently, specific software has been developed to estimate skeletal muscle force distribution during dynamic situations, using motion capture based data (Delp et al., 2007). To date, such estimations have not been reported with regard to dynamic activities, such as the squat. The aim of the current investigation was to examine the influence of the front and back squat variants on the forces produced by the different skeletal muscles. A study of this nature may provide important information for those involved in resistance training, providing evidence of the extent of recruitment for the key muscles associated with two widely used variants of the squat.

Methods

Participants

Twenty-five male participants (age 24.7 SD 4.4 years, height 1.7 SD 0.1 m and body mass 75.4 SD 5.2 kg), volunteered to take part in the current investigation. Participants had 6.24 ±2.21 years of experience in squat lifting with 1 repetition maximum values of 127.5 ±18.8 and 90.6 ±14.4 kg for the back and front squat lifts respectively. Participants trained at least 3 times per week and habitually utilized both squatting techniques as part of their resistance training routine. Ethical approval was obtained from the University Ethics Committee, and the procedures outlined in the Declaration of Helsinki were followed.

Procedure

Participants completed five repetitions in each squat condition, using their normal back and front squat technique. The load was consistent for both conditions, with participants lifting 70% of their front squat 1 repetition maximum. Participants completed their squats in a randomised order. To acquire ground reaction force information, the right foot was positioned onto a piezoelectric force platform (Kistler, Kistler Instruments Ltd., Alton, Hampshire) which sampled at 1000 Hz.

Kinematic information was captured at 250 Hz using an eight camera optoelectric motion analysis system (Qualisys^{TM} Medical AB, Goteburg, Sweden). To define the anatomical frames of the trunk, pelvis, thighs, shanks and feet retroreflective markers were placed at the C7, T12 and xiphoid process landmarks and also positioned bilaterally onto the acromion process, iliac crest, anterior superior iliac spine, posterior super iliac spine, medial and lateral malleoli, medial and lateral femoral epicondyles and greater trochanter. Carbon-fibre tracking clusters comprising of four non-linear retroreflective markers were positioned onto the thigh and shank segments. Static calibration trials were obtained with the participant in the anatomical position in order for the positions of the anatomical markers to be referenced in relation to the tracking clusters/markers.

Data processing

Dynamic trials were digitized using Qualisys Track Manager in order to identify anatomical and tracking markers then exported as C3D files to Visual 3D (C-Motion, Germantown, MD, USA). Ground reaction force and kinematic data were smoothed using cut-off frequencies of 25 and 6 Hz with a non-phase shift low-pass Butterworth 4th order filter.

OpenSim software (Simtk.org) was used to quantify muscle forces during front and back squat lifts (Delp et al., 2007). Muscle force simulations were quantified using the standard gait2392 model using Opensim v3.2. This model corresponds to the eight segments exported from Visual 3D and had 19 total degrees of freedom. The trunk was considered to be a single segment capable of three planar rotations. The pelvis was associated with six degrees of freedom as it was able to rotate and translate in all three axes. The thigh segment was considered to possess three rotational degrees of freedom and was modelled as a ball and socket at its proximal end. The shank and foot segments were considered to possess a single (sagittal plane) rotational degree of freedom and modelled as hinge joint at their proximal ends.

The gait2392 model features ninety two muscles, eighty six of which are centred around the lower extremities and six are associated with the pelvis and trunk. The muscle properties were modelled using the Hill recommendations based on the associations between force-velocity-length (Zajac, 1989). These muscle properties were then scaled based on each participant's height and body mass based on the recommendations of Delp et al. (1990). Following scaling a residual reduction algorithm (RRA) was utilized within OpenSim, this followed the inverse kinematics and ground reaction forces that were exported from Visual 3D. The RRA protocol works by calculating the net joint moments required to re-produce the dynamic motion. The RRA calculations performed on the experimental data all produced route mean squared errors of less than 2°, which corresponds with the recommendations provided by OpenSim for good quality data. Following the RRA, the computed muscle control (CMC) procedure was then employed to estimate a set of muscle force patterns allowing the model to replicate the required kinematics (Thelen, Anderson, Delp, 2003). The CMC procedure works by estimating the required muscle forces to match the net joint moment.

Following the CMC procedure peak and average forces during the squat movement were calculated for the Psoas Major, Iliacus, Gluteus Maximus, Biceps Femoris long head, Biceps Femoris short head, Semitendinosus, Semimembranosus, Rectus Femoris, Vastus Medialis, Vastus lateralis, Vastus intermedius, and Erector Spinae muscles from the right side. The timing of the initiation and termination of the squat movement for both techniques were taken as the instances of maximum hip extension in accordance with those of Sinclair, McCarthy, Bentley, Hurst, Atkins (2014). The net peak muscle force values (N) were normalized by dividing by the participants' body mass, allowing muscles forces to be expressed as N.kg.

Sagittal plane kinematic measures from the hip, knee and trunk which were extracted for statistical analysis were 1) peak angle during the squat and 2) angular excursion from initiation of movement to peak angle. Joint mechanics were computed as a function of the distal segment relative to the proximal segment (hip = thigh relative to pelvis, knee = shank relative to thigh, ankle foot relative to shank and trunk = trunk relative to pelvis). These variables were extracted from each of the five trials for each condition and the data was then averaged within subjects for statistical analysis. Participant's joint kinematic and curves were time normalized from 0–100% of the squat phase and were ensemble averaged across subjects for visual purposes only.

Statistical analyses

Differences in muscle forces and sagittal plane kinematics from each squat condition were examined using a multivariate analysis of variance with significance accepted at the $p < 0.05$ level (Sinclair et al., 2013). Follow up comparisons were utilized in order resolve significant differences between squat conditions. Effect sizes were calculated using a partial Eta^2 (pη^2). All statistical analyses were conducted using SPSS v22.0 (SPSS Inc., Chicago, USA).

Results

The overall multivariate analysis was significant $F = 4.58$, $p < 0.05$; Wilk's $\Lambda = 0.245$, p$\eta^2 = 0.56$. The results indicate that whilst the kinematic curves from the two conditions were qualitatively similar, squat technique significantly affected the outcome muscle kinetics and joint kinematics. Table 1–2 and Figure 1 present the muscle force distributions and joint kinematics obtained as a function of different squat techniques.

Joint kinematics

Peak trunk flexion was shown to be significantly greater ($F = 14.57$, $p < 0.05$, $p\eta^2 = 0.39$) in the back squat in comparison to the front squat (Figure 1). No significant differences ($p > 0.05$) in hip, knee and ankle joint kinematics were observed between the two conditions.

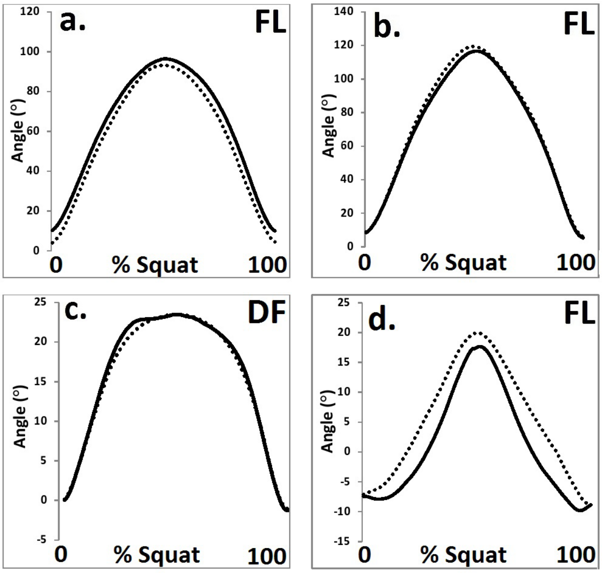

Figure 1. Sagittal plane kinematics of the a. hip, b. knee, c. ankle and d. trunk as a function of the different squat techniques (black = front, dot = back) (FL = flexion, DF = dorsiflexion)

Muscles forces

Peak force in the erector spinae was found to be significantly ($F = 16.21$, $p < 0.05$, $p\eta^2 = 0.42$) larger in the back squat. No further significant differences in muscles forces were observed between squat conditions (Table 1–2)

Table 1. Peak muscle force distributions as a function of the two squat techniques

Specification	Back squat		Front squat	
	Mean	SD	Mean	SD
1	2	3	4	5
Psoas Major (N.kg)	6.26	2.66	6.13	3.81
Iliacus (N.kg)	6.69	3.44	7.01	3.90
Gluteus maximus (N.kg)	11.24	1.71	10.54	2.87
Biceps Femoris long head (N.kg)	12.92	1.68	12.74	1.46
Biceps Femoris short head (N.kg)	4.86	3.31	4.69	2.59
Semitendinosus (N.kg)	4.98	1.15	4.76	1.22
Semimembranosus (N.kg)	17.91	1.33	17.87	2.09

1	2	3	4	5
Rectus Femoris (N.kg)	9.53	4.93	9.52	4.76
Vastus Medialis (N.kg)	12.45	3.76	12.54	2.42
Vastus Lateralis (N.kg)	21.18	6.18	22.20	3.88
Vastus Intermedius (N.kg)	13.61	4.17	13.30	2.68
Erector Spinae (N.kg)	22.30	5.09	16.46	4.53

Table 2. Average muscle force distributions as a function of the two squat techniques

Specification	Back squat		Front squat	
	Mean	SD	Mean	SD
Psoas Major (N.kg)	1.94	1.87	2.13	1.81
Iliacus (N.kg)	1.97	1.97	2.24	1.89
Gluteus Maximus (N.kg)	1.35	1.38	0.79	0.56
Biceps Femoris long head (N.kg)	7.25	1.79	5.80	1.27
Biceps Femoris short head (N.kg)	1.45	2.56	0.47	0.17
Semitendinosus (N.kg)	2.28	1.06	1.77	0.50
Semimembranosus (N.kg)	8.66	2.76	7.31	2.23
Rectus Femoris (N.kg)	2.96	2.97	2.96	2.94
Vastus Medialis (N.kg)	6.43	2.71	6.02	1.64
Vastus Lateralis (N.kg)	11.57	4.56	11.15	2.44
Vastus Intermedius (N.kg)	7.03	2.76	6.58	1.53
Erector Spinae (N.kg)	8.28	3.57	6.27	3.01

Discussion

The current study investigated the influence of the front and back squat techniques on the forces produced by the key skeletal muscles used in these lifts. This represents the first comparative investigation to examine differences in muscle force production during the front and back squat lifts.

The first key observation from the current investigation was in relation to the kinematic analysis. Flexion of the trunk was significantly greater when performing the back squat, in relation to the front squat. This finding concurs with the observations of both Russell, Phillips (1989) and Diggin et al. (2011) who noted similar increases in trunk flexion when performing the back squat. It is likely that this observation relates to the posterior position of the barbell during the back squat in relation to the front squat, thus the distal end of the trunk segment must be projected forwards to maintain balance.

A major innovation of the current study was to estimate skeletal muscle forces, associate with the performance of the front and back squat. Our findings showed that erector spinae muscle force was significantly larger in the back squat condition when compared to the front squat. It is likely that this finding relates to the increased flexion of the trunk segment during the back squat lift. Although not recognised as a dynamic flexor of the trunk segment, it is likely that the enhanced force output associated with this muscle is related to the increased eccentric force production in this muscle as a function of the increase trunk flexion. This observation opposes the EMG study of Gullett et al. (2009) who found no differences in erector spinae muscle activation between the two squat techniques.

Such conflicting findings may be due differences in techniques used between studies, as muscle forces quantified using inverse kinematic techniques are distinct from surface electromyograpic techniques.

An additional observation pertinent to the current investigation is that no differences in quadriceps or hamstring muscle forces were noted between the two squatting modalities. This observation concurs with those of Gullett et al. (2009) and Stuart et al. (1996) who also showed that lower extremity muscle recruitment measured using surface EMG did not differ between front and back squat conditions. Therefore these findings lead the conclusion that neither the front or back squat conditions confers any additional training benefits over the other in terms of the skeletal muscle force output. It is also pertinent to note that the similarity of findings, when using two very different methods, may justify the potential for the estimation of muscle forces method to be used further, when compared to more traditional assessments of muscle activation and engagement.

There are some limitations to the current investigation that it is important to acknowledge. That the current investigation utilized the same resistance for each squat condition means that the relative load was different for both conditions. This procedure was necessary; however, in the context of this study as the ground reaction force information serves as a key input parameter for the inverse kinematic procedure. Therefore, the same resistance was required in order to allow a fair comparison of muscle forces between conditions. This is important, as using a different resistance in each condition would alter the ground reaction force input as a function of the mass that was being lifted. Finally, that this study utilized a simulation based procedure to quantify muscles forces during the squat may also serve as a limitation. The efficacy of musculoskeletal simulations depends on the underlying mathematical model. Numerous mechanical assumptions are made in the construction of musculoskeletal simulation models (Delp et al., 1990). These predominately relate to the constrained rotational degrees of freedom at the knee and ankle joints and the lack of key muscles such as recuts abdominis, which may lead to incorrectly predicted muscle forces. However, as direct quantification of muscle forces are not possible at this time, the current procedure is the most practicable method of quantifying muscle forces in dynamic movements.

In conclusion, although previous analyses have comparatively examined the mechanics of front and back squat the current knowledge with regards to the differences in muscles forces between the two modalities is limited. The current investigation addresses this by providing a comparison of the muscle forces between the front and back squat lifts in the muscles pertinent to the squat lift. The current study shows that the back squat condition was associated with significantly greater forces in the erector spinae muscle, although no differences were shown in the lower extremity muscles. This indicates that neither the front nor back squat offers any benefits over the other in terms of the training stimulus that they provide for the muscles pertinent to the squat.

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CHANGES IN SELECTED MORPHOLOGICAL PARAMETERS AND BODY COMPOSITION, AS WELL AS MEAN BODY SURFACE TEMPERATURE ASSESSED BY THERMAL IMAGING, IN WOMEN AFTER ABDOMINAL LIPOSUCTION

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Abstract. The aim of this study was to assess changes in selected morphological parameters and body composition, as well as in the mean body surface temperature determined by thermal imaging, in women after abdominal liposuction. As abdominal tissue edema and inflammation often persist after liposuction, body composition and surface temperatures were analyzed 3 months after surgery, during a control visit to the clinic. The 12-week delay allowed to eliminate the confounding effects of post-surgical inflammation on our results. We found a statistically significant decrease in all the analyzed morphological parameters and a change in body composition. A reduction in the subcutaneous fat tissue in the abdomen resulted in upward trends in the surface temperature of most of the analyzed areas, with a highly significant increase in the abdominal area. These studies can be considered pioneering and significant in confirming the role of subcutaneous fat as a factor regulating the body surface temperature.

Key words: liposuction, body component, fat, body temperature, thermography

Introduction

Liposuction involves breaking up and removing the excessively accumulated subcutaneous fat in order to correct the shape and contours of one or several body areas. During the surgery, the excess fat is removed from a selected area, leaving a 1 cm layer of fat under the skin; in this way relatively large amounts of subcutaneous adipose tissue may be removed from the body. (Matarasso, Hutchinson, 2001; *The American*..., 2002) This method can be used to model the abdomen, buttocks, thighs, knees, upper parts of the arms, chin, cheeks and neck.

The most common arguments in favor of abdominal liposuction are the ineffectiveness of diet and exercise in reducing excess body fat and disproportionate physique. The full effect of the surgery is visible after 2–3 months. However, little is known about the physiological, biochemical or metabolic effects of liposuction. During the relatively long procedure, patients are exposed to anesthesia, exchange of fluids and infusion of high doses of epinephrine and lidocaine.

One of the greatest perioperative complications is embolism, resulting from the penetration of the broken-up fat through the blood vessels to lungs or brain, and skin necrosis. Plastic surgeons argue, however, that routine liposuction has very low risk of perioperative complications and therefore is considered to be generally harmless. However, due to the fact that the subcutaneous adipose tissue has nutritional and thermodynamic metabolic functions, proportional to its absolute amount and distribution, it is possible that the removal of subcutaneous adipose tissue may adversely affect metabolism. This is also due to the bidirectional interaction between adipose tissue – a metabolically active organ – and other tissues (Matarasso, Kim, Kral, 1998)

Liposuction is associated with inflammation and change in the flow of heat, which result in a large temperature gradient between the area of surgery and its immediate surroundings. This may lead to thermoregulatory disturbances and changes in the body surface temperature. Therefore, we aimed to determine the changes in some morphological parameters and body composition, and changes in the mean body surface temperature, 3 months after liposuction, compared to baseline levels before the surgery.

The aim of the study was to assess changes in selected morphological parameters and body composition, as well as changes in the mean surface temperatures of the body by thermal imaging, in women after abdominal liposuction.

Material and methods

The study was conducted at the Aesthetic Med Andrzej Dmytrzak Plastic Surgery Clinic in Szczecin, Poland, in 2013–2014. It involved 10 women aged 23–50 years (M = 39.4, Sd = 9.5), qualified for abdominal liposuction. The amount of fat removed during the surgery ranged from 2.5 to 5.0 liters (M = 3.4 L; SD = 0.9). The tests were performed before the surgery and three months after surgery, during the control visit. Each of the participants gave written consent before participating in the study, in accordance with the Declaration of Helsinki.

The study was approved by the Bioethics Committee of the Pomeranian Medical University. ThermaCAM SC500 Flir Systems thermal imaging camera was used, with thermal sensitivity of <0.1°C, and with the use of AGEMA software. Computer imaging analysis was used to prepare the thermograms of the chest, abdomen, back, front and rear surfaces of arms, forearms and hands, as well as the front and back surfaces of thighs and shanks.

Each time the we recorded maximum, mean and minimum temperatures in the designated areas. Analysis concerned mean temperatures (T_{mean}) of the designated areas of the body. The tests were always performed in accordance with the standards of the European Thermological Society, in a room with an area of 12 m^2, humidity of 55–60% and temperature 25°C. The patients were given the recommended acclimatization time of 20 minutes; they remained in the room only in underwear so that the heat exchange with the environment stabilized before the infrared test. We assumed the emissivity of the skin to be 0.98. Photos were taken from a distance of 3 m, with subjects in a standing position (Fujimasa, 1995; Żuber, Jung, 1997; Bauer, Dereń, 2014).

We also performed anthropometric measurements in accordance with the rules adopted after Drozdowski (1998). The measurement of body composition used the bioimpedance method and the Jawon Medical X-Scan Plus body composition analyzer. We determined waist circumference (WC) [cm], body weight [kg], percentage of body fat (PBF), visceral fat mass *VFM) [kg], subcutaneous fat mass (SFM) [kg]), percentage of the total body fat (TF) and body mass index (BMI) ([kg/m^2)].

Analysis

Table 1 shows the means (M) and standard deviations (Sd) for body weight, abdominal circumference, and PBF, VFM, SFM, TF and BMI before liposuction surgery and 3 months after surgery, during the control test. We calculated the significance of differences (dependent Student-t test) at $p < 0.05$.

All the women showed a decrease in the value of all the analyzed morphological parameters and a change in body composition 3 months after liposuction. Body weight of the women fell significantly, on average by 3.2 ±0.86 kg, accompanied by the expected reduction in waist circumference of 3.4 ±2.0 cm.

Liposuction decreased body weight and body-mass index, due to a marked decrease in total body fat (2.5 ±1.57 kg), especially in subcutaneous fat mass, from 19.7 ±7.8 to 17.6 ±6.6 kg, but also in visceral fat mass from 2.6 ±1.3 to 2.3 ±1.3 kg, although the change in the visceral fat was the smallest.

Table 1. Arithmetic means, standard deviations and the results of the Student's t-test for the morphological parameters and body composition of women before and 3 months after liposuction

	M1	SD1	M2	SD2	ΔM1 – M2 ± SD	p value in the Student's t-test
Age	39.4	9.5	–	–	–	–
Body weight [kg]	70.3	11.4	67.0	10.4	3.2 ±0.86	<0.0001
Weist Circumference [cm]	86.3	9.5	83.0	8.1	3.4 ±2.00	0.0007
BMI [kg/m^2]	25.4	2.3	24.4	2.1	1.3 ±0.26	<0.0001
PBF [%]	30.7	5.2	28.0	4.5	2.5 ±1.57	0.0009
VFM [kg]	2.6	1.3	2.3	1.3	0.3 ±0.23	0.0018
SFM [kg]	19.7	7.8	17.6	6.6	2.1 ±1.49	0.0022
TF [%]	22.1	4.5	20.6	3.8	1.5 ±0.94	0.0010

M_1 – arithmetic mean before surgery.
M_2 – arithmetic mean three months after liposuction.

Table 2 summarizes the values of arithmetic means and standard deviations and the results of the Student t-test for the analyzed body surface temperatures of women before surgery and 3 months after liposuction. It shows a statistically significant increase in temperature (T_{mean}) after the liposuction only on the surface of the abdomen, i.e. the area from which a significant amount of fat was surgically removed.

Table 2. Arithmetic means, standard deviations and the results of the Student's t-test for surface temperatures of selected areas of the body before and 3 months after liposuction

	M1	SD1	M2	SD2	ΔM1 – M2 ± SD	p value in the Student's t-test
Chest	34.1	0.6	34.3	0.7	0.1 ±0.24	0.13
Back Upper	33.9	0.8	34.1	0.5	–0.2 ±035	0.21
Arm,Forearm front	32.6	0.6	32.8	0.6	–0.2 ±019	0.26
Arm,Forearm back	32.1	0.3	32.2	0.4	–0.1 ±022	0.32
Hand front	31.9	0.6	31.7	0.7	0.2 ±0.52	0.24
Hand back	31.6	0.5	31.4	0.5	0.2 ±0.48	0.19
Abdomen	33.5	0.8	34.0	1.0	0.8 ±0.31	**0.0003**
Back Lower	33.7	0.8	33.9	0.7	0.3 ±0.17	0.22
Thigh front	31.7	0.4	31.7	0.3	0 ±0.26	0.76
Thigh back	31.2	0.5	31.0	0.4	0.2 ±0.41	0.43
Shank front	31.3	0.3	31.3	0.2	0 ±0.15	0.89
Shank back	31.3	0.4	31.2	0.3	0.0	0.80

M_1 – arithmetic mean before surgery.
M_2 – arithmetic mean three months after liposuction.

Discussion

This study is part of the project on the changes in the bodies of women following abdominal liposuction. Its aim was to determine changes in selected morphological parameters and body composition, and in the mean temperatures of selected areas of the body surface, taking into account local differences between those areas in healthy subjects with normal weight. Morphological parameters included weight, BMI, waist circumference, while body composition included lean body mass, body fat percentage, visceral fat mass, subcutaneous fat mass and percentage of body fat in the trunk.

Despite the surgeon's efforts to achieve technical perfection and maximum safety, each liposuction surgery leads to the destruction of some of the blood vessels supplying the skin, and damage to the cutaneous innervation. The regeneration of skin innervation and some other adverse changes may persist for some time. In this study, no serious complications occurred in any subject following liposuction surgery, and all were able to return to their usual lifestyle within one week after liposuction. Because abdominal tissue edema and inflammation can occur for a long time after liposuction, body compositions and surface temperatures were determined 3 months after the surgery, during a control visit to the clinic. The 12-week delay allowed to eliminate the confounding effects of post-surgical inflammation on our results.

Nearly 65–70% of body fat accumulates in the subcutaneous tissue. Patients with central obesity accumulate both visceral and abdominal subcutaneous fat. Subcutaneous adipose tissue is a typical anabolic organ with a large capacity. Chronic excessive supply of energy results in the subcutaneous adipocyte hypertrophy and increased number of adipocytes (Unger, 2003).

Recently, liposuction has been the subject of studies that concerned the durability of its effect and the potential impact on metabolism. Authors often present divergent opinions, and some find no metabolically favorable effect, as only part of hypertrophic adipocytes are removed during the surgery, while the remaining hypertrophic visceral adipocytes still affect the body's insulin resistance (Simka, 2007).

As expected, in our research liposuction in the abdominal region resulted in a reduction in abdominal circumference. Changes that occurred in the composition of the body related to both subcutaneous and visceral fat, and additionally the decrease in measured fat mass, were consistent with the amount of fat aspirated during liposuction (3.4 ±0.9 L). The relationship between the endocrine activity of the adipose tissue and function of the thyroid hormone justified by their close relationship with the control of energy balance and, above all, insulating function of fat tissue, led us to hypothesize on the possibility of changes in the surface temperature of the body following liposuction surgery, which could be estimated through thermography.

Some authors have reported that subcutaneous fat layer has some influence on the skin temperature. Significant correlation between thigh skin temperature and thigh skinfold thickness ($r = -0.488$, $p = 0.020$) over rectus femoral muscle have been observed (Bandeira, Moura, Souza, Nohama, Neves, 2012). Another research investigated the difference of skin temperature in the abdominal region between obese and normal weight groups, and the correlation between abdominal skin temperature and body fat percentage was 0.545, while the abdominal skin temperature of obese group was lower than in the normal weight group (Savastano et al., 2009). Similar relationships were shown by Neves et al. who observed that subjects with lower subcutaneous fat layer had a higher skin temperature variation rate during exercise than those with a thicker subcutaneous fat layer (Neves et al., 2015).

The body thermal response varies according to each body region; moreover, it shows significant individual differences, depending on the parameters of body composition. In our previous study on these relationships in people with extremely different body compositions, women with simple obesity (BMI greater than 30) had significantly lower mean temperatures on the surface of the abdomen and thighs (i.e. areas with the largest proportion of body fat) than women with normal weight. It is worth noting that the mean temperatures (T_{mean}) in those areas in obese women significantly negatively correlated not only with BMI or body fat percentage, but also with the content of subcutaneous fat and the amount of visceral fat (Chudecka, Lubkowska, Kempińska-Podhorecka, 2014).

Our previous study on women diagnosed with anorexia nervosa showed significantly higher temperatures (T_{mean}) on the surface of the abdomen, lower back and thighs compared to women with normal weight, while significantly lower temperatures on the surface of hands. The mean surface temperature of the abdomen significantly negatively correlated with BMI, PBF (percentage of body fat), SFM (subcutaneous fat mass) and VFM (visceral fat mass) (Chudecka, Lubkowska, 2016).

This study was first to evaluate temperature changes in certain areas of the body in patients with a precisely defined surgical reduction in subcutaneous fat tissue. Our research can be considered as pioneering and having significant role in the confirmation of subcutaneous fat as a factor regulating the temperature of the body surface. Reduction of subcutaneous tissue in the abdomen caused upward trends in the surface temperature of most of the analyzed areas, with a highly significant increase in the abdominal area ($p = 0.0003$).

Adipose tissue, because of its reduced thermal conductivity and increased insulatory capacity provides an insulating barrier to conductive heat flow and reduces the body's ability to respond to changes in core temperature, which is confirmed by our observations. Our results suggest that the thickness of the subcutaneous fat layer influences the skin temperature at resting. It can be concluded that subcutaneous fat layer acts as a thermal barrier against muscle heat dissipation.

Interestingly, in the area of upper and lower extremities (hand front and back, thigh front and back) we not only recorded growth trends in surface temperature, but we could only consider them to be downward trends. Our findings suggest that, reduced heat loss related to high abdominal fat is accompanied, under thermoneutral conditions, by augmented heat dissipation from the hands. Furthermore, Savastano et al. found that obese participants had warmer fingernail bed temperatures than the normal weight people (David et al., 2009)

In summary, our results indicate that liposuction removal of abdominal subcutaneous adipose tissue in normal-weight subjects lead to significant increase in abdominal surface temperatures with a slight decrease in the temperature on extremities measured under thermoneutral conditions. This research thus provides additional evidence that body regions of decreased adiposity intensify core-to-skin heat loss and that the heat dissipation from peripheral regions, such as the hands, is blunted.

Some limitations of our study must be noted. First, there was a small number of participants. Second, thermal distributions may also be dependent on physiological differences between participants, such as hydration, stage in menstrual cycle or medication use. Unfortunately, those factors were not taken into account in the present study.

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EFFECT OF AN EDUCATIONAL PROGRAM ABOUT GAME STATISTICS AND A GOAL-SETTING INTERVENTION IN A COMMUNITY COLLEGE WOMEN'S VOLLEYBALL TEAM

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Abstract. The aim was to assess an educational program about game statistics and a goal setting intervention in a community college women's volleyball team. The sample consisted of 12 players from a Midwestern community college women's volleyball team. A quasi-experimental design with a pre-test, post-test, and re-test was done. The dependent variable was the players' perception and use of the game statistics. The independent variable was the educational program about game statistics and goal setting. The coaches' and players' perception, level of satisfaction, and completion of the task during the sessions were recorded. Data were collected through questionnaires and interviews. A descriptive and inferential analysis of the results (t-test for evidence of relationship) was done. After the educational training, the players' perceptions of their ability to understand, analyse, and use information about game statistics and do goal setting in practice and in competition increased significantly. The players used the information significantly more in their practice for all the game actions. Players believed that the abilities they learned helped to improve their performance and the way they practiced. The players believed that the intervention was useful, that it helped them to focus in practice, and that it helped them to focus on technique and the quality of the actions, as well as to better monitor their progress. The educational program was effective with regard to increasing players' perception and understanding about statistics and in the use of statistics and goal setting in practice for monitoring the quality of their actions and their progress.

Key words: team sports, performance, coaching, goal-setting, game statistics

Introduction

In sport, game statistics involve the categorization of the players' actions that are carried out in practice and competition. Usually, the categorization of the actions' efficacy is done in relation to the effect of the actions on the game (error, continuity, or point) or ideal movement pattern (Palao, Morante, 2013). Coding the actions in numbers allows for a mathematical analysis of the data (occurrence, percentages, coefficients, ratios, etc.) (Schleuder, 1998). This allows coaches to carry out a numerical study of the players' and teams' actions in order to make decisions based on their abilities. Typically, coaches use game statistics after receiving education about them in their formal training to be coaches. However, players receive information about statistics without receiving training. This risks the players not properly understanding or internalizing this information. In volleyball, the use of game statistics is common to monitor players and teams in practice and in competition (Palao, Hernandez-Hernandez, 2014). In the literature, it is possible to find information about technical-tactical performance indicators (i.e. Mesquita, Palao, Marcelino, Afonso, 2013), reference values (i.e. Peña, Rodríguez-Guerra., Buscà, Serra, 2013), and theory about how to set goals for practice and for competition (Burton, Raedeke, 2008; Weinberg, Butt, 2014).

Several studies have shown the positive effect of goal-setting and the aspects that must be considered with regard to motivation when this psychological technique is used (e.g. Vansteenkiste, Mouratidis, Van Riet, Lens, 2014; Zetou, Papacharisis, Mountaki, 2008). Less is known about the way to introduce players to monitoring their technical and tactical actions and goals or how to train them in this. The numerous actions carried out by the players in practice make it difficult for coaches to monitor players' goals. This could be the reason why coaches and athletes find goal- setting only moderately effective, due to the players' limitation in obtaining feedback about their actions and internalizing it (Burton, Raedeke, 2008). No data are available regarding how players understand and internalize this information or the level of self-monitoring used in their practice and competition. Therefore, although coaches are using this kind of information to guide their decisions and actions, it is not clear whether the terminology, type of calculations, focus, number of criteria, etc. are adapted for their use by the players.

Another aspect to consider is the way this process is implemented within the teams. Teams usually have a specific member or several members of the coaching staff who do the statistics. This person is the one who carries out the data collection, analysis, and data report. However, there is no information regarding how players monitor their actions in practice and competition, if they do. Educational training could be a tool to introduce and enhance the utility and productivity of game statistics in sport. This could help players to be more aware of the important aspects of the game, to know which actions they have to work on, and to see which aspects they should emphasize in practice and competition in the long-term. This could help the coaching process be more centered on the athlete (Hendry, Hodges, 2013; Vansteenkiste et al., 2014). The aim was to assess the educational program about game statistics and the goal setting intervention in a community college women's volleyball team.

Method

The sample consisted of 12 players from a U.S. Midwestern community college women's volleyball team (2012–2013 season). The sample had an average age of 18.8 ±1.7 years, height of 1.71 ±0.07 meters, weight of 65.52 ±8.00 kg, and experience of 7.2 ±2.1 years of playing volleyball. The coaching staff was composed of a head coach, two assistant coaches, and a strength and conditioning coach. The characteristics of the coaching staff were an average age of 38.8 ±3.7 years and an average experience of 10.2 ±4.6 years coaching volleyball. The players usually stayed in the program two years. One of the assistant coaches performed the team statistics as required by the competition's organizing committee. Her functions and data collection protocols were set by the team's conference and the National Collegiate Athletic Association (2012). The sample was selected due to accessibility. The coaches and the athletic department of the college accepted the invitation to participate in the study. All players were informed of the study and its goals. They completed a consent form before starting the educational training. The educational training was integrated as part of the training done by the team.

A quasi-experimental design with a pre-test, post-test, and re-test was done. The dependent variable was the players' perception and use of the game statistics. The independent variable was the educational program about game statistics and goal setting. The intervention program was carried out in the pre-season, and the follow-up was carried out during the competitive season (14 training weeks). Also, the coaches' and players' perception and level of satisfaction about the educational program was monitored, as was the completion of the tasks done by the players during the sessions. Data were collected through questionnaires and interviews. The program had four 30-minute theoretical-practical sessions outside of the gym and three sessions of 30 minutes in the gym. Players were taught how to set goals and monitor their actions. A wall poster was used to monitor the team goals related to game statistics.

The educational training attempted to give the players the ability to know: what are game statistics?, what types of calculation can be done?, how are data evaluated?, and how can I use game statistics to improve?. The structure of the theoretical-practical sessions outside of the gym was 15 minutes of information presented with the use of slides, video, and combining information with examples; 10 minutes of an applied task (e.g. how to read a match report, how to interpret data, how to monitor and register an action from a video, etc.); two minutes of multiple choice questions to evaluate the knowledge acquisition; and three minutes to review these questions. The structure of the practical sessions in the gym was 3–4 minutes of task explanations, 2–3 series of 4–8 minutes to perform the task, and 3–4 minutes of monitoring the actions, recording the information, linking the qualitative and qualitative execution, and reviewing the process.

During the sessions, players were taught to evaluate their action's efficacy in practice and to extract the information from the match report. Individual and collective goals were set by the players. From the analysis of the previous season's statistics (statistics of the team, the other conference teams, and teams that attended the National Championship), reference values were set (Tables 1 and 2). When establishing the players' values, player positions were taken into consideration (Table 3). In order to connect the quantitative monitoring with improving a certain technique, a set of key aspects were given to the players to review their technical execution when they did not achieve their goals. The key aspects were determined by the coaches and the researcher in order to maintain the same correction criteria in the feedback that the players received in practice. Self-record sheets were used to set the individual goals and to monitor the actions during practices and register information from match reports. The team goals were placed on a poster. Coaches placed stickers on the poster after each game. After the

Table 1. Reference values for terminal actions and actions of continuity by team (data from the winning team of every match from the previous season of the community college athletic conference that was studied, 2010–2011 season)

By Set	Serve		Attack		Block	
	occurrence	percentage	occurrence	percentage	occurrence	percentage
Errors	1–2 per set	<10	5 per set	<15	1–2 per set	<10
Continuity			15 per set	45		
Point	2–3 per set	>10	14 per set	>40	2–3 per set	>10
	Reception		Assist		Digs	
Errors	1 per set	5				
Continuity	1 per set	5				
Perfect	18 per set	90	11 per set	35	18–19 per set	>50

To obtain players' values, divide by number of players involved in these actions on your team.
Teams achieved 25 points through points obtained from the serve, attack, block, and opponent errors (which accounted for 6–7 points).

educational training, the team integrated the monitoring into practices. Coaches promoted its use but did not force it. The team goals were monitored during the entire season.

Table 2. Reference values for terminal actions and actions of continuity (U.S. National Community College Championship, 2010–2011 season)

By Set	Serve		Attack		Block	
	occurrence	percentage	occurrence	percentage	occurrence	percentage
Errors	1 per set	<10	4 per set	<12	1–2 per set	<10
Continuity			14 per set	<40		
Perfect	3 per set	>10	17 per set	>50	3 per set	>10
	Reception		Assist		Digs	
Errors	1 per set	5				
Continuity	1 per set	5				
Perfect	18 per set	90	14 per set	>40	20 per set	>60

To obtain players' values, divide by number of players involved in these actions on your team.
Teams achieved 25 points through points obtained from the serve, attack, block, and opponent errors (which accounted for 4–5 points).

Table 3. Theoretical importance of the different actions in relation to player position

Position	Theoretically most important aspects
Outside hitter	Serve (errors), reception (errors), hit percentage and digs (total)
Middle blocker	Serve (errors), hit percentage, blocks (total), and digs (total)
Opposite	Serve (errors), hit percentage, blocks (total), and digs (total)
Setter	Serve (errors) and assists
Libero	Serve (errors), reception (errors), and digs (total)

The questionnaires used to collect the data were designed ad hoc and they were validated by two experts in sport performance, coaching, or goal-setting (content validity). The questionnaires evaluated the players' perception of the game statistics and their use. The experts and the head coach reviewed the questionnaires and evaluated the adequacy, pertinence, and vocabulary. After the educational training, the level of perception and knowledge of the players about game statistics was measured. After the season, an interview was carried out with the players and the head coach. The interviews were done by the researcher using video-conference. The interview questions focused on the effects of the educational training and the skills learned on their engagement, understanding, and usage, as well as an overall evaluation of the process. The researcher performed the analysis of the qualitative data on the interview transcripts and the resulting themes for the purposes of reporting. A descriptive and inferential analysis of the quantitative results (Wilcoxon Test for evidence of relationship) was done.

Results

After the educational training, players' perception of the importance of the statistics for the public and media increased significantly (Table 4). Their perception of the importance of the statistics for coaches and players did not change (initial and final values >9.5 out of 10). Players' perceptions of their ability to understand, analyse, and use statistics in practice and in competition increased significantly. The players used the information significantly more in their practices for all the game actions. Players believed that the abilities they learned helped to improve their performance and the way they practiced. The players believed that the intervention was useful, because it helped them with technique and the quality of their actions in practice, as well as to better monitor their progress. In relation to the educational training, the players' average involvement was adequate for sessions outside of the gym (65% task achievement) and good for sessions in the gym (>70% task achievement).

Table 4. Players' perception of the effect of skills learned (values expressed on a scale from 0 to 10 and by percentage)

	Before		After		p
	Mean	SD	Mean	SD	
Importance for coaches	9.91	0.30	10.00	0.00	0.315
Importance for players	9.30	1.06	9.60	0.97	0.460
Importance for media	6.73	1.95	8.40	1.71	**0.024**
Importance for public	5.27	2.28	8.20	1.75	**0.017**
Understanding	6.20	1.99	8.80	0.79	**0.005**
Analyzing	5.50	2.12	8.40	1.51	**0.005**
Applying to practices	5.50	1.43	8.60	1.17	**0.005**
Applying to competition	6.10	1.97	8.50	1.35	**0.005**
Level of use	5.40	1.99	9.00	1.15	**0.026**
Serve	7.60	1.90	9.30	1.06	**0.017**
Pass	6.20	1.75	8.80	1.40	**0.005**
Set	5.10	2.13	8.10	1.79	**0.005**
Attack	6.60	2.88	9.10	1.29	**0.010**
Block	6.40	2.95	8.50	1.43	**0.017**
Dig	6.50	1.84	9.10	1.10	**0.005**
Improved performance (%)	–	–	100.00	0.00	–
Improved practice (%)	–	–	91.90	0.32	–

From the analysis of the interviews, three general themes emerged that summarized the players' and head coach's responses to the intervention. These are listed as (a) increased knowledge and skills, (b) change in players' perspective of the way to practice, and (c) more awareness regarding their actions.

a) Increased knowledge and skills. The educational training involved an increase in the players' perceptions of their ability to understand, interpret, and use statistics. During the interviews, players commented:
"…I look more at the numbers and use them in practice" [Player #2] "…now it's part of daily training" [Player #6]

b) Changing players' perspective of the way to practice. The educational training affected the way players executed their practice, as well as their desire to work harder. During the interviews, the players and head coach commented:
"It really hasn't affected my involvement much, but it has influenced the way I practice" [Player #2], "Now I compete with myself and try to improve my stats every day" [Player #1], "Makes you work harder in practice" [Player #10], "Gives sense to practice, monitoring our work, work-out… Really helps us as a team" [Head Coach].

Specifically about the poster, they commented:

"…part of daily training" [Player #2]; "Gave us team bonding time" [Player #8], and "High impact… we wanted more stickers" [Player #1].

c) More awareness regarding their actions. The educational training involved an increase in the players' perceived ability to understand, interpret, and use the information and goal setting. During the interview, the players and head coach commented:

"It makes me realize that I have to work really hard during practice" [Player #3], "It makes me focus on the right thing during practice" [Player #4], and "They realize where they are and that they had to work really hard to achieve their goals" [Head Coach].

About the poster, they specifically commented:

"It helped us to figure out what we should be working on in our next practice" [Player #2]; "It made me focus on the right thing during practice" [Player #4]; "The poster changed our goals" [Player #10]; and "It helps the players realize where we were and what we have to achieve in order to be successful" [Head Coach].

Discussion

The goal of the present study was to assess the effect of an educational program about game statistics and a goal-setting intervention on a sport team. In the interpretation of the data, the facts that the data came from one team and there was no control group should be taken into consideration. This case study is a first step in the development of educational training protocols for monitoring players' technical and tactical actions. Data show that the educational program was effective for increasing players' perception regarding their understanding of statistics, as well as their usage in practice to monitor their quality and progress. The results suggest that this could be considered a step to increase player participation in the coaching process (Hendry, Hodges, 2013).

Players indicated that the intervention increased their knowledge and understanding, their ability to analyse the data, and their ability to apply the skills learned in practice. The increase in knowledge and understanding seems logical because most of the players had not had previous training about these skills, and during the intervention they obtained specific training and individual and collective feedback. The absence of a control group does not allow us to know about the possible effect of an expectancy on the player's perception (Thomas, Nelson, Silverman, 2011). The educational training was determined to be positive and useful by players. The training program that was tested complements the proposal for developing goal-setting skills proposed by Burton, Raedeke (2008). The characteristics of team sports involve the need for players to self-monitor during practice. In addition to providing information, the tested protocol involved acquiring and implementing a goal-setting process, providing information about the technical and tactical performance indicators, and how to monitor and use this process to evaluate themselves.

This educational training involved the players learning to monitor their actions and specific common tasks, such as analysing box scores or match reports or monitoring their actions during practice. All this individual feedback was combined with collective feedback (match report and poster) from the coaching staff. Thus, the training that was done involved the same activities that players had to do during a normal week: play a match, analyse the data obtained from the game (match report), monitor their actions in practice, try to improve, and so on. Therefore, the protocol was tested in real situations and with experienced athletes. Another aspect that must be considered regarding the intervention is that the performance goals (action efficacy) of the different actions were connected to process goals, key indicators of the actions. The objective, besides monitoring themselves, was to involve players in their actions, and to make them reflect on what they have to pay attention to or change. This combination of individual and team monitoring about process and performance aspects allows us to obtain measurable goals of their actions that they can use in practice (Burton, Raedeke, 2008).

Indirectly, the findings showed that the information and skills provided to the players was adequate for their level, and they understood and used them. The data were expressed to the players in ratios expressed in relation to 10 (e.g. three kills of 10 attempts) (Palao, 2008; Schleuder, 1998). This mathematical expression was selected in order to make it easier for players to monitor their actions. Therefore, although coaches manage game statistics using percentage, occurrence per set, ratios, or coefficients, the information was always presented to the players in ratios to increase the chances of players applying the data in their practice. The integration of applied theory with the normal, everyday practice of the athletes could also be a key aspect of the results found with this team. More research is needed about the language coaches should use to communicate with their athletes in order to enhance this process (Kristiansen, Tomten, Hanstad, Roberts, 2012).

From the comments of the players, the educational program also contributed to an increased involvement of the players or the way that players carried out their practice. The reason for this may be due to players having reference values to achieve individually and collectively, players having the ability to monitor themselves, or players participating in the process of establishing their individual and team technical and tactical goals. These results coincide with the effects or benefits of goal setting found by Burton and Raedeke (2008). This educational training works with players that have seven years of experience. The sample studied had automated the techniques, so they were able to have an external focus during their technical executions. With a sample of community college players, the skills that the players learned allowed them to challenge themselves. The combination of the possibility of obtaining information, feedback, and having reference values is probably the reason for the “awareness” that the players and the head coach commented on in the interviews. Knowing their level, their evolution, and the level needed to achieve the national competition makes them realize where they are and how much work is needed to achieve their goals. This correction of their self-perception is a normal adjustment caused by the original lack of skills to properly estimate their level (Kruger, Dunning, 1999). Previous research about the effect of goal setting has found that although its use is positive with younger players (Zetou et al., 2008), with more experienced players, this effect is not as clear, probably due to the number of aspects that affect their performance (Goldsmith, 2008; Hopkins, 2004).

For the team that participated in the study, the effect of the educational training was positive, and it helped the coaches give their athletes meaning to the practices and work-outs. The proposal increased the involvement of players in their training process by giving them skills to monitor their actions and reference values to evaluate these actions (O’Donoghue, Mayes, 2013). This knowledge can increase their awareness of their actions, their procedural knowledge, and their engagement in the process (Hendry, Hodges, 2013). Also, it will allow better integration for the players in the monitoring process of the training, which allows them to be more involved in the process, even more autonomous, and less dependent on the game-to-game dynamic (Vansteenkiste et al., 2014). Previous studies have shown the positive effect of reflective mentoring by coaches on elite players’ procedural knowledge, decision making, and performance (Moreno, Moreno, Urena, Iglesias, Villar, 2008). However, it is not clear whether these abilities increase during the formation process (Araujo, Afonso, Mesquita, 2012). This experience introduces the possibility that systematic and deliberate theoretical-practical training for players of the skill of self-monitoring their actions (game statistics) could help to develop players' awareness about their actions and affect the procedural knowledge, decision making, and performance. Future studies are needed to confirm these findings in teams of different levels, gender, age groups, etc., with the use of a control group, and while assessing the effect on the quality of the practice and player improvement.

Conclusions

The educational program increased players' perception and understanding of statistics as well as their use in practice to monitor the players' quality and progress. The findings show that teaching players to monitor and evaluate their actions in practice and in competition increases the involvement of the players and the awareness of their needs. The steps and materials developed in this study can be used as a reference for the way to introduce these knowledge and skills to players. The study involved providing knowledge and skills about how to monitor the efficacy of their actions, the aspects of the execution to review if the efficacy level was not achieved, and reference values to analyse their data, as well as how to set collective and individual goals. More studies are needed to assess the proper vocabulary, tasks, protocols, etc. to adapt theory to practice and to the level of the players.

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THE ASSOCIATIONS OF SELECTED LIFESTYLE PATTERNS AND LUNG CANCER RISK: AN EVIDENCE-BASED UPDATE

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Abstract. Diagnosis of lung cancer (LC) has been fraught with difficulty and by the time of definitive diagnosis, most patients are in later stages of the disease. Epidemiological studies have demonstrated that lifestyle behaviors play an etiological role in LC risk; however data in the literature on this topic often appears inconclusive or require further study. Understanding of the mechanisms operating between lifestyle patterns and their impact on LC is important for the disease's prevention and treatment. The purpose of this study was to review the current evidence on the role of diet, body mass index (BMI), physical activity, smoking, alcohol consumption, and sex hormone use in LC development based on meta-analyses, systematic reviews and previously published epidemiologic studies. Regarded as the foremost cause of LC, evidence from studies have indicated that tobacco smoking causes LC. Additionally, exposure to outdoor air pollution and/or occupational-related exposures increase LC risk. Further, frequent consumption of red meat, processed meat increases adenocarcinoma and squamous cell carcinoma. Inverse associations between the disease risk and BMI ≥25 kg/m^2, higher level of physical activity, and fruit and vegetable consumption with a high frequency were reported. Future studies are warranted to validate the association between histologic subtypes of LC and lifestyle patterns.

Key words: lung cancer, physical activity, diet, body weight, alcohol consumption, smoking, sex hormone

Introduction

Lung cancer (LC) is the leading cause of total cancer incidence and mortality worldwide with a 5-year survival rate of <10% (Ferlay et al., 2015; Jemal et al., 2011; Zahir, Mirtalebi, 2012). Four major histologic subtypes of LC have been differentiated: small-cell carcinoma, large-cell carcinoma, adenocarcinoma, and squamous carcinoma (Devesa, Bray, Vizcaino, Parkin, 2005). Adenocarcinoma and squamous carcinoma are the most frequently diagnosed subtypes of the total number of LC; which accounts for about 30–40% and 30%, respectively. LC incidence varies among geographical regions particularly in the developed countries, with considerable increases observed in some developing countries (Ferlay et al., 2015). Epidemiologic studies have recognized tobacco smoking as the dominant risk factor for LC (Wu, et al., 2014b; Yuan et al., 2012), accounting for 90% of male cases and 79% of female cases (Khan, Afag, Mukhtar, 2010). There are estimates that the risk of LC development among lifelong active smokers is 20–40 times higher than nonsmokers (Ulas et al., 2015). Additionally, second hand tobacco smoke has been established as a risk factor with the percentage of LC attributed to passive smoking accounting for 3–5% (Emaus, Thune, 2015). According to the National Cancer Institute, non-smoking individuals exposed to passive smoking have about a 20% increased risk of the disease compared to non-smokers and individuals not exposed to secondhand smoke (NCI, 2011). However, approximately 10–20% of LC cases have been identified among people who never smoked (Khan et al., 2010). Furthermore, there is a potential synergistic interaction between tobacco smoking and occupational and environmental exposures to lung carcinogens, like polycyclic hydrocarbons, asbestos, radon, arsenic, chromium, nickel, and cadmium (Environmental Protection Agency 2011; Kim, Jahan, Kabir, Brown, 2013; Raaschou-Nielsen et al., 2013; Saracci, 1987; Straif et al., 2009). Age, race, and a positive family history of LC have been confirmed as risk factors for the disease (Lissowska et al., 2010; Matakidou, Eisen, Houlston, 2005; Pinsky, 2006). During the last five decades, research has focused on the role of diet, physical activity, and other modifiable lifestyle patterns in the etiology of some cancers, including LC. Given the presence of several gaps in the findings in etiology of LC, such as the cancer in people who never smoked, a small percentage of smokers with diagnosed cancer, and difference in incidence rates only in men, a higher risk of LC in African Americans compared with other racial/ethnic groups (National Cancer Prevention, 2015), a growing body of research has focused on modifiable lifestyle factors that may modify the risk in active and passive smokers or to increase susceptibility to the disease in people who never smoked. Some studies have presented the benefits of regular physical activity of moderate intensity (Buffart et al., 2014; Emaus, Thune, 2011; Mao et al., 2003), obesity (Thun et al., 2008), and fruit and vegetable consumption (Bunn Jr., 2012; Butler et al., 2013; Ruiz, Hernández, 2014). Others have reported significant or non-significant higher risk of LC associated with consumption of animal fats, red meat, and processed meat (Gnagnarella et al., 2013a; Gnagnarella et al., 2013b; Lam et al., 2009), and alcohol consumption (Korte et al., 2002). However, some research findings on the association of lifestyle determinants with LC require further examination of the current evidence. Because LC is a multifactorial disease with a high incidence rate in men and women, it is important to continue updating the current evidence on the role of modifiable risk factors in the disease etiology. Providing further evidence on mechanisms of lifestyle factors that influence LC risk may help in the primary prevention of the disease thereby reducing mortality. This paper examines the most updated evidence on the relationship between the major modifiable risk factors and their contribution to LC development and risk. The aim of this paper is not intended to be a review on this topic, but to highlight key risk factors and relevant examples of lifestyle patterns on LC risk.

Diet and lung cancer risk

Epidemiological studies investigating the causal association between nutrition and LC have shown that dietary risk factors may accounts for 30–35% of modifiable risk factors for cancer (Ruiz, Hernández, 2014) due to the influence of nutrition on the regulation of the cell cycle (WCR/AICR, 2007). Poor dietary patterns are second to tobacco smoking as a major risk of LC worldwide. Dietary patterns are classified into two categories as it relates to disease prevention: (1) diets characterized by a rich consumption of vitamins, fiber, fruits and vegetables, olive oil, whole grains, green tea, and fish; or (2) diets characterized by an increased consumption of animal fats, red meat, processed meat, saturated fats, and refined sugars. Evidence have been proposed regarding the strength of the diet – LC risk association as the relationship has been found to be dependent on histologic subtypes of LC and smoking status (Büchner et al., 2010); though, data on this dependence seems to be inconsistent. This lack of consistency may be attributable to the limited number of studies on this topic. A recent systematic review by Koutsokera et al. (2013) studying the relationship between dietary patterns and LC found that 11 cohort and case-control studies suggested a reduction in LC risk with consumption of fruits and vegetables. The authors also found an increased LC risk with higher intake of red and processed meat. The group concluded that most researchers observed an inverse association between fruit and vegetable consumption and LC risk, and only some studies found a beneficial effect with only fruit consumption. A recent population-based case-control study of 2,101 primary LC cases in Italy by Lam et al. (2009) that was not included in the above review reported an elevated risk of LC among smokers by 80% and by 70% for red and processed meat consumption, respectively. In addition, the group reported higher LC risk among people who never smoked (OR = 2.4, 95% CI = 1.4–4.0 for red meat intake and OR = 2.5, 95% CI = 1.5–4.2 for processed meat intake). Another recent review of epidemiological research by Ruiz, Hernández (2014), which examined the literature dating back prior to October 2013, on the preventive roles of omega–3 and omega–6 fatty acids against several cancers including LC, concluded that there is no clear evidence regarding the preventive roles of these compounds. The relationship between diet and the risk of LC was confirmed in a few recent studies not included in the aforementioned reviews. For example, Butler et al. (2013) reported an increased risk of lung adrenocarcinoma with high-temperature cooked meat intake by 51% (hazard ratio, HR = 1.51) using data from a large prospective study from Singapore (1,130 cases identified from 61,321 subjects who never smoked). In contrast, the group observed no association between fried meat consumption and LC risk of non-adrenocarcinoma, especially among subjects who never smoked. Another recent prospective study (4,336 heavy smokers, among them 178 cases) also reported increased LC risk by 73% for frequent red meat intake (Gnagnarella et al., 2013a). Further, the group showed a 44% significant decrease in the risk (HR = 0.56, 95% CI = 0.31–0.99) for one or more cups of tea consumed daily compared to non-tea consumers and a 90% risk reduction for a Mediterranean-style diet (HR = 0.10, 95% CI = 0.01–0.7). Consistent with this study, Mukti et al. (2014) observed an increased risk of LC by 93% with high intake of red meat in a case-control study of Bangladeshi people. Additionally, a previous study reported a significant risk reduction with vegetable fat consumption (Gnagnarella et al., 2013b). Takata et al. (2013) large cohort study of Chinese men (61,491 individuals, 359 cases, 68.8% identified as smokers) indicated that consumption of green leafy vegetables and carotenoid-rich vegetables were significantly associated with lower LC risk by 28–56%. In turn, Lugman et al. (2014) studied the association between dietary patterns and LC risk in a case-control study in Pakistan (400 cases and 800 controls). The study findings showed that OR for LC was positively associated with consumption of red meat (OR = 2.9, 95% CI = 1.8–4.7), chicken (OR = 2.8, 95% CI = 1.4–4.9), tea (OR = 1.8, 95% CI = 1.2–2.6), and coffee (OR = 1.8, 95% CI = 1.1–2.8). In contrast, consumption of vegetables, juices or fruits, decreased LC risk by 70%, and consumption of milk by 40%.

Several plausible mechanisms have been hypothesized to explain how processed meat and fresh red meat increase cancer risk. Meats are rich sources of protein but during the high temperature processing of meats, saturated fatty acids and other compounds such as heterocyclic amines, N-nitroso compounds, aldehydes, polycyclic aromatic hydrocarbons are produced (Lam et al., 2009; Ramirez, Estévez, Morcuende, Cava, 2004; Ruiz, Hernández, 2014; Sugimura, Wakabayashi, Nakagama, Nagao, 2004). Experimental studies recognized these compounds as both mutagenic and carcinogenic. For example, N-nitroso compounds have been found to induce

DNA damage (Eichholzer, Gutzwiller, 1998). Usage of nitrate or nitrite salts for the preservation and color of meats contribute to the production of DNA-damaging nitrosamines (ACS). In addition, meats, which are rich sources of total fat, saturated fat, and cholesterol, increase the concentration of secondary bile acids that are able to participate in carcinogenesis. Further, dietary heme iron in meat may contribute to an increased LC risk as donor or receptor of an electron, being involved in the Fenton reaction (Fe (II) + $H_2O_2 \rightarrow$ Fe (III) + $HO^{\bullet}$ + OH^{-}) (Valko et al., 2007). The Fenton reaction and the reduction of the iron ion by superoxide anion radical, $O_2^{\bar{\bullet}}$ (Fe (III) + $O_2^{\bar{\bullet}} \rightarrow$ Fe (II) + O_2) has been recognized as a key source of the most powerful oxidant in a cell such as hydroxyl radical, $HO^{\bullet}$. In organisms overloaded in iron disturbance between oxidant formation and the antioxidant defense capacity in cells with excessive production of reactive oxygen species (ROS) and nitrogen species is related to oxidative stress (OS). Such a cell's state characterized by excessive generation of ROS is a key regulatory mechanism for cancer stem cells and cancer due to DNA damage directly and/or to formation of N-nitroso containing compounds, thus plays a considerable role in the initiation and progression of cancer (Filaire et al., 2013; Lam et al., 2009). Although several previous and recent studies have suggested that a diet rich in red meat and processed meat may serve as risk factors for LC; there are also many studies that report inconsistent findings. The Second Expert Panel concluded that the epidemiological evidence for these dietary patterns are *limited* and *inconsistent*, respectively (WCR/AICR, 2007). The lung organ is directly exposed to environmental pollutants and ROS produced during chronic inflammation, especially in tobacco smokers. The oxidants can induce modification of DNA, lipids, proteins, and activate the mitogen-activated protein kinase signaling that lead to inflammation and activation of nuclear transcription factors (Valko et al., 2007). Several consequences of DNA damage in lung under OS conditions have been reported, among them replication errors and genomic instability. It is theoretically accepted that prooxidant reactions play a key role in the initiation, promotion, and progression of cancer (Filaire et al., 2013). Therefore, dietary antioxidants are especially important in the protection against LC, particularly for smokers as inhibitors of free radicals that are present in cigarette smoke (Weng, Yen, 2012). Dietary antioxidants may reduce DNA damage caused by ROS, thereby protecting against LC risk. The prevention of cancer through a diet rich in fruits and vegetables have been attributed to the presence of vitamins (A, B6, B12, C, D, folic acid), minerals, carotenoids, fiber, flavonoids, indoles, and phenolic compounds. Many of these compounds are inhibitors of ROS and play an important role as low molecular weight antioxidants, enhancing the endogenous antioxidant system. Polyphenolic compounds may protect against cancer as antioxidants by several metabolic reactions due to the modification in cell adhesion, migration, and angiogenesis (Garcia-Tirado, Rieger-Reyes, Saz-Peiro, 2012; Weng and Yen 2012). Weng, Yen (2012) reported that the polyphenolic compound resveratrol (occurring in high concentration in red grapes), caffeic acid, and pomegranate flavonoids were found to protect against LC. Vitamins and minerals, found in fruits and vegetables, can act synergistically and serve a beneficial protective effect against cancer. Interestingly, vitamin and mineral supplementation in pills that are equivalent to levels found in fruits and vegetables were not found to have such protective effects. Moreover, there is evidence that high-dose supplement intake has the potential to increase cancer risk (Albanes, 1999). In recent years, evidence has been suggested that natural glycoproteins are important biologically active compounds with anticancer properties. Present in plant cells; glycoproteins found in green tea possess strong antioxidant potential. Anti-tumor actions of glycoproteins are attributed among others, to the influence of immune system response, the reduction of inflammation, killing of tumor cells, activation of tumor necrosis factor (TNF), and the blocking of tumor cell differentiation. Recent studies provide evidence that immune function-enhancing pharmaceuticals that mitigate side effects of chemotherapeutics have been found to be effective in LC therapy (Yuan, Liu, Dai, Song, 2015). While an increased consumption of fruits and vegetables seem to have a protective effect against LC risk due to their antioxidant ability, some studies reported no protective association (Liu, Sobue, Otani, Tsugane, 2004). Further studies are warranted to investigate how particular components of a diet could affect histological subtypes of LC, which also take into account gender and smoking status. Moreover, the consumption of fruits and vegetables may influence cancer risk through their influence on overall energy intake. In addition, individuals that consume a diet rich in vegetables and fruits are usually more physically active. Due to a diverse range of genetic abnormalities of LC cells, Wood, Pernemalm, Crosbie, Whetton, (2014) reported possible gene – environmental interactions, dependence of DNA repair mechanisms, and inflammation of an individual's genes. The report from World Cancer Research Fund/American Institute for Cancer Research (2007) stated that the evidence regarding non-starchy vegetable intake and a decreased risk of LC to be "limited suggestive", and frequent intake of fruits and vegetables rich in carotenoids as "probable".

Physical activity and lung cancer risk

In the past 25 years, there has been a focused interest in the preventive role of moderate or high levels of physical activity (PA) and cancer risk (primary prevention) and the use of PA as a safe complementary treatment for patients with cancer (secondary prevention) (Albrecht, Taylor, 2012; Emaus, Thune, 2011; Kruk, Czerniak, 2013; Lee et al., 2012; Lee, Sesso, Paffenbarger, 1999; Lowe, Watanabe, Baracos, Courneya, 2010; McTiernan, 2008; Speck et al., 2010). The term PA, as described in epidemiologic studies, has included household, occupational, recreational (for pleasure or competitive aim), and transportation activities (Caspersen, Powell, Christensen, 1985). In order to categorize energy expenditure, a combination of frequency, duration, and intensity of activity should be accounted, based on a resting metabolic score (MET), i.e. an equivalent to quiet sitting which for the average weighted adult equals to 4.181 kJ × kg^{-1} body weight × h^{-1} (Ainsworth et al., 2000). According to the MET score, four levels of PA intensity are distinguished in epidemiologic studies: sedentary or inactive (1.0 ≤ 1.6 MET, e.g. sleeping, watching TV), light (1.6 ≤ 3.0 MET, e.g. yoga), moderate (3.0 ≤ 6.0 MET, e.g. walking), and vigorous (≥6.0 MET, e.g. running) in order to categorize energy expenditure (Norton, Norton, Sadgrove, 2010). For primary prevention, there is *limited* evidence from observational studies that physical activity protects against LC risk according to a 5-degree scale of the Second Panel judgments (WCR/AICR, 2007) ("convincing, probable, limited suggestive, limited – not conclusion, substantial effect on risk unlikely"). To date, the biological mechanisms by which PA may reduce LC risk are not fully understood, but there are several plausible mechanisms hypothesized linking PA to reduced LC risk (Anzuini, Battistella, Izzotti, 2011; Emaus, Thune, 2011; Friedenreich 2011; Goldstraw et al., 2011; Missaoui et al., 2011; Thune, Lund, 1997). Multiple mechanisms may act cooperatively and some may depend on factors such as level of PA, LC subtype, and smoking status (Lynch, Neilson, Friedenreich, 2011). The first possible mechanism includes increased pulmonary function that may reduce concentration of carcinogens in the airways and duration of air-way exposure to inhaled carcinogens among individuals engaged in PA especially of vigorous intensity (Thune, Lund, 1997). PA may also help to neutralize ROS, which is a known cancer initiator, thus reducing DNA damage caused by these environmental pollutants (Rundle, 2005). It has been suggested that an increase in pulmonary ventilation and perfusion may decrease the risk of small cell-carcinoma and adenocarcinoma cancer subtypes situated mainly in the periphery of the lung. This suggestion, however, appears to be applicable in male patients (Thune, Lund, 1997). Inhaled chemical carcinogens and ROS have been recognized to react with DNA of lung and bronchus cells (Asami et al., 1997; Church, Pryor, 1985). One hypothesis suggests that

PA may be preventive by increasing DNA repair ability through an up-regulation of antioxidant defense systems. Another hypothesis suggests that regular long-term PA improves immune system function through an increase of the number and activity of natural killer cells, and macrophages, and interleukins (IL-1 and IL-2) (Nieman, Pedersen, 1999; Shephard, Rhind, Shek, 1995). A third hypothesis postulates reduction of inflammation. Recent studies have suggested a direct association between chronic inflammation and cancer risk (Klaunig, Kamendulis, Hoceva, 2010; Reuter et al., 2010). This is due to the inflammatory responses to the chemical or particulate exposures, wounds, or microbial infection (Emaus, Thune, 2011). PA of moderate intensity may help reduce generation of proinflammatory cytokines, such as IL-1, IL-6 and tumor necrosis factor-alpha (TNF-α), thereby reducing C-reactive protein (CRP) (Panagiotakos et al., 2005). Both interleukins and TNF-α may affect the growth and differentiation of lymphocytes and stimulate proliferation and differentiation of immune cells. There is, however, no scientific consensus or clarity on the association of PA and reduction of inflammatory cytokines (Sprague et al., 2008). The forth hypothesis in the preventive role of PA is the influence of insulin growth factor–1 (IGF-1)/insulin growth factor binding protein-3 (IGFBP-3) ratio. Higher concentrations of IGF-1 were reported to be linked with increased LC risk (Friedenreich, Orenstein, 2002; Gonullu et al., 2005; Mao, 2003). IGF-1 may act as a mitogen thereby increasing cell proliferation and differentiation (Lynch et al., 2011). In contrast, high levels of IGFBP-3 were reported to be associated with decreased risk (Mao et al., 2003). However, some studies do not confirm an association between IGF factors and LC risk (Ahn et al., 2006; Renehan et al., 2004). Strong and coherent evidence exists for the role of increased oxidative stress in carcinogenesis (Filaire et al., 2013; Klaunig et al., 2010; Kruk, Duchnik, 2014; Laszlo et al., 2014; Manda, Nechifor, Neagu, 2009; Valluru, Dasari, Wudayagiri, 2014; Yeon et al., 2011). Smoking and environmental carcinogenic inhalations are examples of exogenous sources of ROS and nitrogen species. In this respect, regular PA of moderate intensity is hypothesized to protect against LC risk by increasing of levels of antioxidant enzymes (Rundle et al., 2005) and tissue resistance against ROS damage (Kruk, 2011). ROS not only damages DNA but also stimulates inflammatory signal transduction pathways via activation of nuclear factor (NF-κβ). Moderate PA induces an expression of antioxidant genes through the activation of nuclear factor 2 (Nrf2) that participates in the expression of antioxidants (Filaire et al., 2013). These previously described mechanisms that mediate the relationship between regular PA and LC risk may operate synergistically or independently adverse consequences.

Studies from randomized controlled trials (RCT) have provided further insight on the role of PA in cancer etiology. A review of RCT evidence postulates that PA may have a small to moderate effect on improving the concentrations of biomarkers that are potentially involved in carcinogenesis (Winzer et al., 2011). The epidemiologic evidence on the preventive role of PA and LC risk is growing but warrants further examination. A previous meta-analysis by Tardon et al. (2005) that evaluated studies published between 1966 and October 2003 (eight cohort studies and three case-control studies), adjusted for smoking and others confounders, found a protective effect of PA dependent on its intensity (the combined odds ratio (OR), OR = 0.87, 95% CI = 0.79–0.95 for moderate leisure time PA and OR = 0.70, 95% CI = 0.62–0.79 for vigorous activity). The risk reduction was stronger among women compared to men for both levels of activity. Emaus, Thune (2011) analyzed 20 cohort studies (published between 1989 and 2009) and seven population-based case-control studies (published between 1991 and 2008). They found that total and recreational PA may reduce the risk of LC by 20–50% among men and by 20–30% among women; the cancer risk correspondingly decreased with increasing levels of PA, suggesting a dose-response effect. Another review of 21 study samples published between June 1989 and May 2011 concluded that results of the studies were inconsistent; where 10 studies demonstrated a decreased risk of LC among moderate and high physically active subjects, and 11 studies reported no association (Koutsokera et al., 2013). An analysis of the studies published between 1996 and October 2003 indicated that leisure-time PA may protect against LC risk. Evidence of a negative association between PA and LC risk was confirmed in a subsequent meta-analysis of 14 prospective studies (1,644,305 participants, 14,074 cases) published between 1989 and 2009 (Sun, Shi, Gao, Xu, 2012). The authors found that both high and medium levels of PA were linked with a significant decrease in LC risk among total participants (men and women) compared to individuals characterized by low level of activity (RR = 0.77, 95% CI = 0.73–0.81 and RR = 0.87, 95% CI = 0.83–0.90, respectively). A recent meta-analysis of seven cohort studies and one case-control study demonstrated that PA reduced LC risk significantly (RR = 0.82, 95% CI = 0.77–0.87), however the authors did not observe dose-response relationships between PA levels and LC risk (Buffart et al., 2014). Further, they reported no differences in the risk among heavy and light smokers. Steindorf (2013) reported that 29 publications supported recreational PA to be effective in reducing LC risk by up to 20–30% among women and 20–50% among men. Another recently published meta-analysis by Zhong et al. (2016) reviewed 12 cohort studies and six case-control studies (2,468,470 participants, 26,453 cases) and demonstrated a protective effect against LC risk of any amount of PA (RR = 0.79, 95% CI = 0.73–0.86) and similar risk reduction among individuals engaged in high PA compared to low PA. Further evidence in the protective association between PA and LC risk was confirmed in a few recent epidemiologic studies not included in the aforementioned analyses. Schmidt et al. (2012) analyzed 158 LC-affected and 144 control cases from the Cologne Smoking Study (CoSmoS) (a retrospective case-control study) and found that PA was associated with a reduced risk of LC in current or former smokers. Individuals who were physically active at least one hour/week were at a significantly lower risk compared to those not physically active (OR = 0.53, 95% CI = 0.28–0.97); however, the authors were not able to characterize precisely the intensity and frequency of the subjects' activity. Parent et al. (2011) in a case-control study (857 LC cases and 533 controls) conducted in Montreal, Canada, found that participation in sports and/or outdoor activities of average once weekly or more for at least 6 months decreased LC risk by about 31% (OR = 0.69, 95% CI = 0.52–0.91). The authors also observed a statistically insignificant reduction in LC risk with lifelong occupational PA (OR = 0.86, 95% CI = 0.49–1.52). For the combined occupational and recreational PA during adult life, a 34% significant LC risk reduction was observed. Sormunen et al. (2004) examined the association between lifetime PA and LC risk in a cohort of 2448 elite male athletes and 1712 controls in Finland between 1986 and 2010. The research group found a strong LC risk reduction; with a standardized incidence ratio of 0.40, 95% CI = 0.27–0.55 among athletes. Further, the authors concluded that, on the whole, athletes were less likely to develop any cancers than the general population, especially lung and renal cancer as a consequence of less frequent smoking and other healthy lifestyle patterns. A prospective cohort study by Lam et al. (2013) of 158,415 participants with no history of smoking involved in the NIH-AARP Diet and Health Study (532 cases, identified over 11 years of follow-up) found that individuals who spent ≥3 hours/day sitting had an increased LC risk by 32% compared to those who spent <3 hours/day sitting. Interestingly, they did not observe an association for participation in vigorous PA. A recently published prospective population-based cohort study (73 LC cases identified during an average follow-up of 20 years of 2305 individuals with no history of cancer at baseline) of Finnish men examined the relationship between cardiorespiratory fitness (CRF) and leisure-time PA (LTPA) (Pletnikoff et al., 2016). The study demonstrated a protective effect of CRF against LC (RR = 2.89; 95% CI = 1.14–7.22, p = 0.02) accounting for VO_2max mean 40.49 mL/kg/min relative 20.28 mL/kg/min in the model adjusted for age, year of examination, family history of cancer, smoking, education, alcohol consumption, vegetable and fruits intake. However, in a multivariate model, the relationship between LTPA and LC risk was found to be insignificant. A lack of association between LTPA and LC in fully adjusted models were reported by Brizio et al. (2016) based on a case-control study (81 cases, 168 controls) in Brazil.

PA appears to play an important beneficial role for patients with LC. Patients with LC experience a poor health-related quality of life and a high prevalence of psychological stress. According to a systematic review of 16 studies on the role of PA interventions for patients with non-small cell LC, PA decreased symptoms of the disease, improved quality of life, and physical capacity (Granger et al., 2011). Further, CRT studies that evaluated the effects of PA intervention on fatigue and quality of life patients with LC showed improvement of fatigue, quality of life, and a beneficial effect on physical and psychological symptoms (Dhillon et al., 2012; Jensen et al., 2014). A latest study by Wang et al. (2015) that evaluated the influence of chronic diseases and PA on quality of life among LC survivors in Shanghai (China), found that PA exerts a beneficial effect on quality of life only in those survivors with chronic diseases.

Previous epidemiological studies have consistently shown that PA plays an important role in the reduction of risk of LC risk, particularly in current or former smokers and improved physical well-being of cancer survivors. The majority of studies reported that recreational and total PA reduced LC risk on average by 20–30% in women and 20–50% in men, although, most of these studies on association between LC risk and PA involved only men with some authors reporting a protective effect of PA on the disease in men but not in women (Thune, Lund, 1997). Other studies indicated that PA of moderate or vigorous intensity is linked with a decreased risk among both genders (Sun et al., 2012). The influence of PA on carcinogenesis can vary depending on intensity, frequency, and duration of activity, smoking history, energy intake, body weight, gender, alcohol consumption, genetic susceptibility, and other environmental factors. There are limited data regarding the relationship of LC risk with PA in people who never smoked; although several studies suggested a lack of difference in the association regarding smoking status (Lee et al., 1999; Mao et al., 2003). It has been suggested that regular PA of moderate/high intensity improves pulmonary function, thereby reducing the concentration of carcinogen compounds and their deposition in the airways and reduces the duration of the carcinogenic agents-airway interaction. Moreover, PA causes changes in the concentration of pro-cancer growth factors such as IGFs and IGFBPs, reduces inflammation, enhances immune function, and improves DNA repair. Several researchers have underlined the beneficial role of regular PA of moderate intensity in adapting to oxidative stress by up-regulating superoxide dismutase and glutathione peroxidase. In contrast, single exhaustive PA can increase oxidative stress that is hypothesized to play an etiological role in LC development. In the systematic review of the existing evidence the World Cancer Research Fund 2007 rated the evidence as “limited suggestive” that PA lowers LC risk (WCRF/AICR, 2007). The observed inconsistency of findings may be due to the fact that there are possible interactions between PA, diet, smoking, and obesity. Individuals who are physically active tend to lead healthier lifestyles i.e. less likely to smoke, to be obese, to drink alcohol, and frequently consume vegetables and fruits compared to those who are more sedentary (Kruk, 2010).

Excess body weight and lung cancer risk

Overweight (Body Mass Index, BMI ≥ 25.0 ≤ 30kg/m^2) and/or obesity (BMI ≥ 30kg/m^2) (WCRF/AICR 2007) were reported as significant risk factors for most cancers (Reeves et al., 2007; Renehan 2011; Renehan, Roberts, Dive, 2008). There are several proposed biological mechanisms to explain this association, among them are: high levels of insulin resulting from increased concentrations of leptin, resistin, TNF-α, and fatty acids released from adipose tissue. These biomolecules may promote cellular proliferation and inhibit apoptosis (Calle, Kaak, 2004).

The association of overweight/obesity with LC risk is not well described and warrants further investigation. Some researchers reported that low BMI (<18 kg/m^2) increased LC risk independently of smoking status, weight loss, and other confounders among both genders and for women who never smoked (Kabat, Wynder, 1992). A recent cohort study with 12,052 males by Li et al. (2015) reported increased LC risk by 80% among Asian men with BMI <18.5 kg/m^2 compared to those with BMI 18.5–24.9 kg/m^2. Further, the authors found that men with BMI ≥25 kg/m^2 had a significant decrease in LC risk (RR = 0.65, 95% CI = 0.49–0.88) and those with BMI ≥30 kg/m^2 had a non-significant decrease in LC risk (RR = 0.64, 95% CI = 0.30–1.37). A meta-analysis of 12 studies selected between 1966 and 2013 confirmed a significant increased LC risk in men with BMI <18.5 kg/m^2, significant decreased risk in men with BMI ≥25 kg/m^2 and BMI ≥30 kg/m^2, compared with normal weight subjects. When the authors stratified on subgroups based on geographical regions, a significantly increased risk by 47% in individuals with BMI ≤18.5 kg/m^2 was found only among East-Asian men but not among other populations. The authors also found that excess BMI compared to normal BMI significantly decreased chromosomal damage, therefore LC risk. These findings support the existing literature that increased methylation at the hypoxia-inducible factor (HIF)-3 alpha locus in adipose tissue and in blood can decrease the expression of HIF-3α of a factor able to potentially mediate LC and gene-obesity interaction (Pasanen, Heikkilä, Rautavuoma, 2010). A previous meta-analysis of prospective studies by Renehan et al. (2008) showed a significant decrease in the risk with a 5 kg/m^2 increase in BMI in a dose-response effect. Also, further evidence from another meta-analysis (Yang et al., 2013) of cohort and case-control studies found that overweight and obesity may protect against LC risk in both genders. The authors underlined that there is a varying effect of BMI on the development of LC in men and women. The mechanism of inverse association of BMI with LC warrants further investigation.

Smoking, alcohol consumption, and lung cancer risk

Tobacco smoking has been firmly established as a major primary risk factor for LC; smokers have an 8–13 times higher risk compared to non-smokers (Katanoda, Marugame, Salka, 2008; Lugman et al., 2014; Mukti et al., 2014; Wu et al., 2014b). About 4000 chemical constituents, including pharmacologically active, toxic, mutagenic and carcinogenic compounds such as N-nitrosamines and alkaloids have been identified in cigarette smoke (Asami et al., 1997; Fowles, Dybing 2003; Yuan et al., 2012). Exposure to tobacco carcinogens generated by active smokers (environmental tobacco smoke) can cause LC in nonsmokers (Besaratinia, Pfeifer, 2008; Couraud et al., 2012). According to Vollset, Tverdal, Gjessing (2006), smoking is responsible for 1.8 million cancer deaths per year worldwide and 80–90% of LC deaths are among people 40–70 years of age (Kamsa-Ard et al., 2013). The risk increases with the initiation of smoking at an early age, as well as longer smoking periods. Smoking has contributed considerably to health care costs. For example in 2008, the total economic cost of LC caused by smoking reached in 2008 \$2.234 billion in men and \$870.0 million in women in South Korea (Oh et al., 2012), and \$12.0 million in Morocco (Tachfouti et al., 2012). Recent advances have been found to help elucidate the differences in the development of LC between smokers and non-smokers (Yano et al., 2011; Wu et al., 2014b). Wu et al. (2014b) have carried out a meta-analysis of 19 case-control studies that included 2,287 LC cases (63.4% smokers). The authors found an approximately 30% higher risk for Ras-association domain family 1 isoform A gene hypermethylation (RASSF1A) in smokers than in non-smokers. This gene was found to reduce tumorigenicity in *vivo* and its damage resulting from methylation associated with cigarette smoking which can be an important agent in LC etiology. This, however, does not explain the high risk observed among smokers, which may point to possible effects of other variables (age, gender, ethnicity, lifestyle). Smoking exerts various influences on the occurrence of specific subtypes of LC, from the strongest initiator in small-cell carcinoma to the weakest in adrenocarcinoma (Koutsokera et al., 2013). Polycyclic aromatic hydrocarbons (PAHs) and the most potent compound nitrosamine present in cigarette smoke and occupational exposure were reported to cause chromosomal damage, thereby causing genomic instability (Asami et al., 1997; Kim et al., 2013). However, even statistical models accounting for BMI, PA, and alcohol consumption linked with smoking and LC failed to eliminate the strong confounder of cigarette smoking. A large prospective cohort study (Lam et al. 2013) of 532 LC cases identified from 158415 individuals who never smoked found no beneficial effects of BMI at baseline or middle age on LC risk compared to Li et al. (2015) study. Differences in the effect of BMI on LC risk based on smoking status are still not well recognized. One possible explanation for these differences suggests that LC in people who never smoked has a unique etiology occurring mainly as the adenocarcinoma subtype and EGFR mutations (Lam et al., 2013). Cigarette smoking is often reported to be linked with poor dietary patterns and alcohol intake (Alberg, 2002). Several studies have examined the potential link between alcohol intake and LC risk. A pooled analysis of cohort studies (7 prospective studies, 399,767 participants and 3,137 LC cases) indicated a 21% increase in LC risk in men and a 16% increase in women for intake ≥30g of alcohol/day compared to those consuming no alcohol (Freudenheim et al., 2005). The authors observed an increased risk of LC among men who never smoked with an intake of ≥15 g alcohol/day compared to men who declared no alcohol consumption (RR = 6.38, 95% CI = 2.74–14.9) and a lack of association in smokers.

Findings from epidemiological studies evaluating the effect of both alcohol intake and smoking on LC risk indicated that an increased risk was reported more frequently in hospital case-control studies than in population-based case-control studies (Korte et al., 2002). However, the findings from some epidemiologic studies often appeared conflicting. Further studies are needed in order to clarify whether alcohol consumption acts as an additional risk factor in smokers. Several biological mechanisms have been proposed to explain the effect of alcohol consumption on LC risk (Chiolero et al,. 2006; Dupont et al., 1998; Kukiełka, Cederbaum, 1992; Manautou, Carlson, 1991; Wright, McManaman, Repine, 1999). One proposal suggests that a reaction between ethanol and alcohol dehydrogenase generating acetaldehyde of what may be a substrate for xanthine oxidoreductase, which, in turn, triggers generation of superoxide radical, H_2O_2, and hydroxyl radical in the Fenton reaction (Jaganjac et al., 2013). Another proposed mechanism involves the effect of ethanol on NADH and NADPH dependent production of ROS (Kukiełka, Cederbaum, 1992) owing to the enhancement of cigarette smoke carcinogens (Hamajima et al., 2002).

Oral contraceptive use, hormone replacement therapy, and lung cancer risk

With the understanding that LC is a multifactorial disease that can be dependent on gender, some evidence have suggested a link between hormonal factors and LC (Siegfried, 2010). Consequently, it is important to present the current state of evidence regarding the possible role of estrogens in LC development. It is well documented that most carcinogens require activation to generate intermediates or products able to form covalent binding with DNA bases. According to the mechanism of steroidal estrogen metabolism, summarized by Kruk and Aboul-Enein (2006), the transformation of estrogens involve production of several products such as ROS, semiquinones, and catecholestrogens that are capable of modifying DNA, RNA, proteins and cause lipid peroxidation. Research on the association between estrogen use and cancer risk have found an increased risk for some cancers (e.g. breast, liver) and a decreased risk in others (Wu et al., 2014a). Several meta-analyses have examined links between the use of estrogens and LC risk, however their findings appear inconclusive (Chen, Cai, 2009; Pesatori et al., 2013; Wu et al., 2014a). Pesatori et al. (2013) reported a statistically significant decrease in risk compared to Baik et al. (2010) who found an increased risk among long time estrogens users (>5 years). Chen, Cai (2009), however, observed no association. Similarly, Wu et al. (2014a), in an updated meta-analysis of 14 cohort and case-control studies found a lack of a significant association between oral contraceptive use and LC risk. However, the authors observed a 26% decrease in risk among European oral contraceptive users and a 10% borderline significant effect in women with adrenocarcinoma. The differences in these findings may, in part, be explained by the decreased concentration of estrogen content and the addition of progesterone acting as an antiestrogen (Qin et al., 2013). Moreover, estrogens can interact with compounds from tobacco smoke and influence their metabolism as well as estrogen receptor signaling. Their effects may be dependent on histologic subtypes (Siegfried, 2010). Further studies on large groups of cases able to perform analyses with histological subgroups of LC, dose, and duration of estrogen use, adjusting for tobacco smoking and other potentially recognized confounders are warranted.

Conclusion

There is growing scientific evidence indicating that lifestyle factors may exert independent effects on LC development. Knowledge of the relationship between LC risk and lifestyle components provide an opportunity to reduce the incidence of this disease. There is supportive evidence which indicates that about 33% of LC may be preventable by health changing behaviors (Gauci, Delikata, 2011). However, several unanswered questions remain due in part, to the fact that smoking is a very strong factor for LC risk and attenuates the relationship between LC risk and other lifestyle determinants, even after adjustment for this confounder. Tobacco smoke exposure, arsenic, and asbestos have been consistently established as risk factors for LC. However, the literature have shown that this type of cancer may never develop among current smokers while occurring among individuals who never smoked. The current literature underlines the importance of limiting the consumption of animal fats and red meat, increasing vegetable, fruits, and whole grain intake, avoiding excessive weight gain and at least 150 minutes of regular PA of moderate intensity or 75 minutes of vigorous intensity each week as healthy lifestyle factors in LC prevention. Primary LC prevention continues to be the avoidance or cessation of tobacco smoking. Consistent with these findings, the American Institute for Cancer Research (2010) estimates that 36% of LC cases “could be prevented annually through a healthy diet, regular physical activity, and being lean”. In addition, a role of synergistic reactions between cigarette smoking and alcohol consumption or asbestos exposure have been found to change an individual’s susceptibility to LC. Evidence shows that modifiable lifestyle patterns are among environmental risk factors that play an important role in the etiology of LC. However, studies evaluating the effects of environmental and lifestyle risk factors on the development of LC require further multidisciplinary studies. These suggested studies should include large sample sizes and potential confounders that characterize the mechanisms by which lifestyle determinants may influence certain histologic subtypes of LC development. Identification of all subclasses of LC and their markers is a priority. Molecular biology research would help ascertain information on DNA, RNA, and proteins damage and the genetic transformation. Of interest are findings dealing with the subclass classification for LC datasets as one of the analysis tools reported over last few years of gene expression research (Engchuan, Chan, 2015). This will help to raise public health in adopting healthier lifestyle patterns and develop strategies and interventions for both the prevention and treatment of LC.

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REPEATED ACCELERATION ACTIVITY IN COMPETITIVE YOUTH SOCCER

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Abstract. Soccer match-play is increasingly characterised by short, high-speed bursts reliant on the ability to accelerate. Performance is impaired after peak acceleration activity and during the second half and may compromise a player's effectiveness. To date, information about repeated acceleration sequences is lacking but would provide further insight into high-speed activity during competition. This study examined repeated acceleration ability (RAA) using GPS (5 Hz) and accelerometer (100 Hz), during 14 competitive youth soccer matches from the 2014–2015 season. Results showed that RAA profiles were relatively homogeneous, and there were no significant differences between playing positions. RAA activity was also relatively stable between playing halves and only the activity of forwards declined significantly. In summary, this study suggests that RAA is a generic requirement of match-play at this level but presents a specific focus for conditioning regimens.

Key words: soccer, youth, repeated acceleration ability, RAA, GPS, performance analysis

Introduction

Recent studies have described the evolution in the physical demands of competition, and increasingly the modern game is punctuated by a greater number of short high-speed bursts (Wallace, Norton, 2014). Between 2006/07–2012/13, total sprint distance increased ~35%; facilitated by a decrease in individual sprint distance and an increase in the number of sprints. Also, the proportion of explosive sprints has increased ~10% (Barnes, Archer, Buchheit, Bradley, 2014) emphasising the importance of acceleration (Wallace, Norton, 2014). Research is unequivocal that maximal accelerations are more frequent than maximal sprints (Varley, Aughey, 2012) and that superior acceleration may present a competitive advantage (Lockie, Murphy, Knight, de Jonge, 2011; Little, Williams, 2005).

Given the importance of accelerating, the ability to withstand their fatiguing effect is essential. Reductions in acceleration capacity are found between halves and transiently during the game. Between playing halves, a decline is reported in the number of efforts (Ingebrigtsen, Terje, Hjelde, Drust, Wisloff, 2015; Russell et al., 2014; Terje, Ingebrigtsen, Gertjan, Harvard, Wisloff, 2015) and the cumulative distance (Terje et al., 2015; Akenhead, Hayes, Thompson, Duncan, 2013; Barron, Atkins, Edmundson, Fewtrell, 2014). Acceleration activity can be reasonably expected to be unevenly distributed throughout a game and lead to very intense periods of repeated activity. During one study, peak acceleration activity resulted in a ~10% reduction in subsequent activity lasting for ~10 minutes (Akenhead et al. 2013). Impaired acceleration ability could, therefore, be expected to impact on the player's effectiveness and reduce the team's offensive and/or defensive potency.

Previous analysis of the most intense periods of match–play has led to the development of repeated sprint activity (RSA) training and testing protocols, yet consensus is lacking whether this is a key component. Some studies have found very limited evidence of RSA during match–play (Buchheit, Mendez-Villanueva, Simpson, Bourdon, 2010; Carling, Le Gall, Dupont, 2012; Barberó-Álvarez et al., 2014) and, it would appear that measuring repeated acceleration activity (RAA) would be more insightful.

RAA is defined as three consecutive acceleration efforts (>1.5m·s^{-2}) interspersed with a maximum of 45 seconds, and the only study to date was conducted on elite field and assistant referees (Barberó-Álvarez et al., 2014). Analysis of the RAA activity of outfield players would further enhance the understanding of the rigours of competition and inform conditioning programmes. The aim of this study was to investigate RAA activity during sub-elite youth competition.

Method

Participants

Sixty-one well-trained sub – elite youth soccer players (17.3 ±0.9 years, 176.93 ±4.31 cm; 63.96 ±4.76 kg) volunteered for the study. Written consent was provided in accordance with the procedures outlined in the Declaration of Helsinki. Approval was granted by the School of Sport, Tourism and Outdoors ethics committee at the University of Central Lancashire. Players were classified by playing position, including; wide defenders (WD = 13), central defenders (CD = 17), central midfielders (CMF = 11), wide midfielders (WMF = 10) and forwards (FW = 10). 14 home English College fixtures were monitored during the competitive phase of the 2014–2015 season. All games were played on a full-size synthetic 3G surface; a 4-2-3-1 formation was preferred and only players completing the full 90 minutes in the same playing position were included for analysis.

Procedure

Portable 5 Hz GPS units (Catapult Sports, Minimax) equipped with a 100 Hz accelerometer were located in a custom built vest and harnessed securely between the upper shoulder blades. GPS units were switched on 10 minutes before use to allow satellite locking consistent with manufacturer's guidelines. Horizontal dilution of precision (HDOP) indicates accuracy of GPS in a horizontal plane and optimum satellite availability (HDOP = 0.0) is where one satellite is directly overhead with a minimum of four spaced equally around the horizon. During these trials, HDOP ranged 0.76–1.32 which is a good signal (Catapult Sports).

Analysis

RAA was defined as three consecutive accelerations >1.5 m·s-2 interspersed with a maximum of 45 seconds. Data was uploaded to Catapult Sprint software (version 5.1.7), and files were filtered to exclude non – game activity, producing 2 × 45 minute periods.

All data was tested for normality using a Kolmogorov-Smirnov and Levene's test established homogeneity. One way ANOVA was used to detect the main differences in the number of RAA bouts and differences between playing positions and playing halves. Significant main effects were investigated with post hoc Bonferroni – corrected multiple comparisons. Non – parametric data was assessed using a Kruskal – Wallis test. Statistical significance was accepted at $p \leq 0.05$ and Pearson's Correlation Coefficient measured effect size where $r = 0.10$ (small effect); $r = 0.30$ (medium effect) and $r = 0.50$ (large effect). All statistical procedures were completed using SPSS 20.0 (SPSS Inc. Chicago, USA).

Results

There was a significant main effect of playing position on the total number of RAA bouts, but post hoc testing revealed no significant differences. Confidence interval data shows that wide players tended to complete more RAA bouts than central positions. There was no significant differences in the number of efforts per bout or recovery duration (see Table 1).

Table 1. Summary of RAA activity by playing position

Position	Total bouts		Efforts per bout		Recovery per effort (secs)		Recovery per bout (secs)	
	mean (±SD)	95% CI	mean (±SD)	95% CI	mean (±SD)	95% CI	mean (±SD)	95% CI
WD	9.15 (3.71)	6.90–11.39	3.78 (0.50)	3.47–4.08	19.75 (2.63)	18.16–21.35	477.09 (353.72)	263.34–690.84
CD	5.56 (3.32)	3.89–7.21	3.52 (0.98)	3.03–4.01	19.23 (5.85)	16.32–22.15	515.34 (394.45)	319.19–711.50
CMF	5.46 (3.86)	2.86–8.04	3.16 (1.09)	2.42–3.90	18.58 (6.97)	13.90–23.26	418.71 (323.55)	201.35–636.07
WMF	10.50 (7.16)	5.37–15.63	3.68 (0.54)	3.29–2.42	18.48 (2.01)	17.03–19.92	385.15 (184.37)	253.26–517.04
FW	6.80 (3.94)	3.98–9.61	3.75 (0.95)	3.33–4.18	16.35 (4.01)	13.47–19.22	562.74 (257.78)	253.26–517.04
All	7.29 (4.70)	6.09–8.48	3.58 (0.81)	3.36–3.78	18.64 (4.80)	17.42–19.86	476.82 (321.85)	395.08–558.56
Sig.	p = 0.02 r = 0.43		p = 0.37 r = 0.30		p = 0.53 r = 0.22		p = 0.72 r = 0.19	

RAA activity was relatively stable between playing halves, and only the activity of FW declined significantly (see Table 2). Collapsed means showed there was no significant decrease between halves, in the number of efforts per RAA bout (2.52 ±1.85 vs. 2.40 ±1.97, $p = 0.49$, $r = 0.05$) or the recovery interval between efforts (13.21 secs ±10.93 vs. 12.22 secs ±10.90, $p = 0.33$, $r = 0.07$).

Table 2. Number of RAA bouts between match halves by playing position (mean ±SD)

	WD	CD	CMF	WMF	FW
First half	4.65 (±1.52)	2.94 (±0.97)	2.64 (±0.85)	5.25 (±1.80)	4.44 (±1.47)
Second half	4.50 (±1.46)	2.62 (±0.85)	2.82 (±0.91)	5.25 (±1.80)	2.85 (±0.93)
Sig.	p = 0.82 r = 0.04	p = 0.46 r = 0.10	p = 0.76 r = 0.14	p = 1.00, r = 0.00	p = 0.04 r = 0.46

Discussion

This study provides evidence of repeated acceleration activity by sub-elite youth soccer players, during competition. Across all positions, the mean number of RAA bouts was 7.09 (±4.70), and there was a main effect of playing position, although there were no significant positional differences identified. There was a trend for wide players to complete more efforts than central, and a moderate effect size (r = 0.43) provides justification for further investigation. On average the number of efforts per RAA bout was 3.58 (±0.81) and again, wide players tended to complete more efforts per bout, compared to central players. The lack of significant differences indicates that the RAA activity was comparable, suggesting it is a crucial attribute for all positions.

Research of RAA is scant, but amongst top – level referees, there were 7.0 (±3.9) RAA bouts and 3.9 (±1.5) efforts per bout during match – play (Barberó-Álvarez et al., 2014). Despite the similarities to this study, comparison is done so cautiously because of the fundamental difference in roles between referees and players. Nevertheless, we conclude that RAA may be a useful measure of high-speed performance in youth soccer. Previously, repeated sprint ability has been proposed as a crucial element of performance (Di Mascio, Bradley, 2013), however, limited RSA activity reported by our group (Barron et al., 2014) and others contradicts these claims (Buchheit et al. 2010; Carling et al. 2012; Barberó-Álvarez et al., 2014) suggesting RAA is a more useful measure.

Recently the link between high speed running and successful performance has been challenged (Bradley et al., 2013). Increasing numbers of short, high-speed bursts are observed (Wallace, Norton, 2014; Barnes et al., 2014) reliant on high rates of acceleration. Maximum accelerations are more frequent than maximum sprints (Varley, Aughey, 2013; Ingebrigtsen et al., 2015; Russell et al., 2015) and are completed at low velocities (Osgnach, Poser, Di Prampero, Bernardini, Rinaldo, 2010), therefore the efficacy of using the number of sprints, or a distance-based index as a performance measure, is questionable (Terje et al., 2015).

Confidence interval data shows that the number of efforts per RAA bout can reach far higher values than suggested by the mean. Although our study did not examine the impact of RAA activity, the fatiguing effect of elevated activity could be expected to negatively affect subsequent work-rate because neuromuscular fatigue is strongly linked to alterations in the force generation capacity of skeletal muscle (Rahnama, Reilly, Lees, Graham Smith, 2003; Rampinini et al., 2011). In a separate study, acceleration capacity was impaired following peak activity and a decrement of ~11% in high magnitude accelerations persevered for ~10 minutes (Akenhead et al., 2013).

During an U-15 competition featuring five games (2 × 25 mins) in three days, the acceleration profile was significantly reduced in the latter games, despite no change in maximum sprinting speed or locomotor activities (Arruda et al., 2015). Similarly, there were no reductions in sprints or high speed running during a similar period, in England (Odetoyinbo, Wooster, Lane, 2007), Scotland (Dupont et al., 2010), Spain (Rey, Lago-Peñas, Lago-Ballesteros, Casais, Dellal, 2010) and France (Carling, Dupont, 2011). These findings may appear inconsistent yet, a fatigued player could be expected to take longer to reach target speed and result in running distance being maintained, masking the impairment of acceleration performance.

Impaired acceleration ability could be supposed to impact on the players ability to move efficiently in tight areas, create space to receive the ball or to press an opponent, for example. However, reductions in physical performance are not necessarily mirrored by declines in technical performance. A comparison of congested and non-congested periods showed the number of passes, the percentage of duels won and touches per possession were unchanged at the elite level (Carling, Dupont, 2011). However, amongst semi – professionals, there were significant declines in passing accuracy, after repeated sprint activity (McMorris, Rayment, 2007), leading the authors to conclude that high-speed exercise deleteriously affects motor control in an amateur population. The ability to resist fatigue is crucial if a player can perform efficient and precise actions continually during competition (Stone, Oliver, 2009), and the superior fitness of the elite players may explain these differences. In this case, it emphasises the need for amateurs to develop their resistance to repeated accelerations.

Unlike technical performance, tactical performance did decline during fixture dense periods, and players exhibited less positional synchronisation at the elite level (Folgado, Duarte, Fernandes, Sampaio, 2014). The field of analytics defines performance as how players, collectively and individually, adapt to the ever–changing configurations of match-play to gain a competitive advantage (Folgado et al., 2014; Gréhaigne, Godbout, Bouthier, 1999). Facing higher tiered opponents required greater synchronisation, and this produced significantly more high (14.4–19.7 $km \cdot hr^{-1}$) and very high speed (>19.8 $km \cdot hr^{-1}$) running. The disparity between the numbers of accelerations and the number of sprints (Varley, Aughey, 2013; Ingebrigtsen et al., 2015), implies effective synchronisation is also dependent on the ability to accelerate repeatedly. By extension, impairment in the ability to accelerate may result in less synchronisation and reduce a team's offensive and defensive potency.

An important limitation of this study is the ability of the 5 Hz Minimax GPS to measure instantaneous changes of speed during acceleration. Underestimations of –5 to –9.6% were reported in comparison to a laser (Varley, Fairweather, Aughey, 2012) implying this data is the minimum values achieved during match – play and that bouts of RAA may be more numerous. Also, due to the nature of the study, it is not possible to directly link a bout of RAA with a key game event. Future research could seek to investigate these links and thereby bridge the gap between physical and technical performance. We acknowledge the relatively small sample size used in this study, but the evidence presented provides sufficient justification to warrant further investigations of RAA in other levels of competition.

Conclusions

In summary, the capacity to accelerate repeatedly is crucial for all playing positions, but probably more important for wide players. The evidence of RAA in this study highlights spells of intense activity that may not be reflected by measures of total distance or the total number of accelerations. Elevated periods of activity lead to time-dependent impairments in physical capacity that may compromise a player's effectiveness. Coaches should, therefore, consider including activities featuring repeated accelerations to optimise preparedness for competition.

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INFLUENCE OF REHABILITATION ON HEALTH OF BALLROOM DANCERS AFTER SPORTS INJURIES

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Abstract. The paper is aimed at assessing the influence of rehabilitation on health of ballroom dancers after sports injuries.
At the turn of 2014 and 2015 ballroom dancers from all around Poland were questioned. The surveyed were professional dancers aged between 13 and 30 years. As many as 63 athletes were injured during their career. The rehabilitation of 47 of them took place in the rehabilitation centre under physiotherapeutic supervision. Only 16 of the injured rehabilitated on their own.
The opinion poll based on the survey was used as a method. The questionnaire included closed and open questions which were to show the influence of injury and its treatment on future sports career. Questions were detailed and referred to the kinds of injuries and their causes, the process of treatment, duration of rehabilitation, its process and results. Questionnaire results were analysed statistically with the use of the Pearson's chi-squared test.
It has been proved that rehabilitation under physiotherapeutic supervision has positive influence on health of ballroom dancers after injuries. Specialist rehabilitation of sportsmen after sports injuries contributed to the shortening of time of the recuperation and to the complete recovery. The time of recovery of the injured who did not undergo the professional rehabilitation was longer, and it was impossible to restore lost functions in the group of 5% of the surveyed, which resulted in the end of their career.
Dancers after sports injures should always undergo professional rehabilitation under the sports doctor's and physiotherapist's supervision.

Key words: dance, ballroom dance, latin dance, sports injuries, rehabilitation

Introduction

The aim of rehabilitation of sportsmen who were injured as a result of sport discipline training is re-establishing the correct anatomical and biomechanical bonds in the injured areas and warranting the return to the sports activity from before the injury. The treatment should be multipart and include the correct diagnostics, immediate specialist therapy and periodical rehabilitation. Not only is the complete healing of damaged structures and their functionality restoration desired, but also the endeavour to re-establish the correct static and dynamic activity in full form.

"Trauma is a kinetic, chemical, thermal factor *etc.* causing tissue damage. While injury is a damage that is a consequence of trauma" (Kita, 2004, pp. 171–175). The scope of injury depends on the kind and the size of trauma, as well as the resistance of a certain tissue. It is caused by the functional or structural disorders which result from the post-trauma biochemical, ultra-structural and micro- or macroscopic changes. Local traumas can be accompanied by various intensified systemic changes. The intensification of these changes depends not only on the individual system reactivity but also on: strength, direction and the type of trauma, the place and the affected organ. Traumatic injuries of the musculoskeletal system can occur as acute or chronic (primary, secondary) injury. Trauma – that can occur during physical sports activity, and its aftermath which results in the exclusion from training (temporary or complete) – is called a sports injury (Widuchowski, Widuchowski, 2005).

The best and most common scheme of the direct post-traumatic procedure is the PRICEMM rule (Kita, 2004; Gawroński, 1998) (Table 1).

Table 1. Post-traumatic procedure – the PRICEMM rule

PRICEMM rule
P – Protection – Support, protection, absolute or relative immobilisation (walking stick, crutch, splint, orthosis, plaster cast, bandage, tape).
R – Rest – (reduction of general and local activity).
I – Ice – ice, cooling (cold appliance, cryotherapy).
C – Compression – (bandage, compression arm sleeves).
E – Elevation – (over the heart, supine position, splint, sling).
M – Mediciation – pharmacotherapy (NSAIDs and other).
M – Modalities – physiotherapy (laser, ultrasounds, electrical stimulation, *etc.*).

There are three phases of healing process (healing of the damaged tissues): acute phase (up to 48 hours), restoration and regeneration phase (from 48 hours up to 6–7 weeks), and the final phase (from 6–8 weeks up to few years). In case of failing to start the treatment, or an improper procedure, the damages may lead to permanent and dangerous dysfunction, not only disabling sports activity but also the daily activity. The treatment can be divided into: operational, preservative, and rehabilitating. The surgical operations aim at restoring the function, activity and the shape of the damaged structures. The preservative treatment includes less invasive surgical treatment (bone set, immobilisation, intra-articular injections, etc.), pharmacotherapy and the elements of rehabilitation. However, rehabilitation (kinesis therapy, physiotherapy, massage) is responsible for the restoration of the joints motion and the muscle strength.

In a complex treatment of injured sportsmen it is essential to take into account various psychological aspects (Olex-Mierzejewska, 1996) which eventually determine the process and the outcome of treatment, and are essential in effective handling of the cognitive, emotional and behavioural consequences of injuries. As J. Heil assumed, injury is a physical and psychological test of strength for a sportsman (Heil, 1993). Undoubtedly, the medical as well as psychological rehabilitation should go together and parallel because various psychosomatic reactions can slow down the restoration process. Therapists can do both: boost the sportsman's perception of the seriousness of the injury, as well as boost the trust in the effectiveness of treatment and the benefits of performing arranged exercises and rehabilitation (Kłodecka-Różalska, 1996). It is known that the sportsman's carrier does not last forever but the worst happens when it ends because of the injury. Sometimes, seemingly not dangerous injury "[…] may annihilate the several months' labour and deprive the sportsman of the possibility of achieving a life success. The medical personnel should respect the athlete's goals. Occasionally, the doctor should protect the sportsman against himself, as well as the society's pressure" (Blecharz, 2009, p. 86). Unfortunately, at times, getting back in shape, from before the injury, is impossible. Therefore the question is: what's next? Thanks to the gained psychological abilities, sportsmen can regain the self-esteem, as well as the complete satisfaction from the way they function and they can prepare more effectively to start a new way.

Small number of sportsmen who are not medically treated show how high is the dancers' awareness. They know, very well, the mechanisms of injuries and the significance of a swift introduction of rehabilitation (Wanke, Quarcoo, Uibel, Groneberg, 2012). They also know which symptoms they should pay attention to and they understand that, in spite of the proper orthopaedic, traumatic or neurological treatment, the disregard of rehabilitation may lead to the disruption or the early end of their sport's career. Sportsmen's motivation to cure the injury is of twofold importance (Wanke et al., 2013) because their main goal is not to achieve a state from before the trauma but to achieve the ability of getting back to intensive training as quickly as possible. In ballroom dancing, apart from the public pressure, the strong incentive is the co-dancer, whom the injury burden affects the most. That is why they expect the fastest recovery of the strength and agility. The desire to get back on the floor results in reliable fulfilment of the doctor's instructions and physiotherapeutic suggestions. Nonetheless, physiotherapists and sports doctors should remember about the very detailed rehabilitation instructions for the sportsman, but mainly the gradual rehabilitation trainings, specifically accordingly to the trained discipline (Sabo, 2013).

Equally serious problem, as the not fully treated injury, is the delayed beginning of the treatment. Quite common – especially among young sportsmen – is dissimulation (Thomas, Tarr, 2009). They do not reveal the troubling disorders, for fear of being excluded from the training, competition or for their position as a partner being diminished.

The main risk factor for injuries in ballroom dancing is its technique, paradoxically. Both, standard and Latin-American dances sometimes require non-anatomical moves, which define the technique level. Unfortunately, what is identified as dancing perfection, in fact, triggers a variety of traumas including the soft tissue deformation, dangerous strain of the tendons, ligaments, fascia and muscles and can finally lead to the habit which may cause arthritic changes in the future. Another risk factor predisposing to trauma is lack of training education course, and the resulting training errors. Next risk is frequent overtraining of sportsmen and training or attending a tournament right after injury, or in the state of extreme exhaustion. Performing sudden, quick moves, often jumps or even run on 7–9 cm high-heels (women ballroom dancers), is also not very safe. The injure risk rises together with psychological stress and depends as well on the technical conditions of the venue.

The aim of the paper was the evaluation of the influence of rehabilitation on health of the ballroom dancers after injuries.

The research issue was the attempt to answer the question: what is the influence of rehabilitation on the time of physical activity recovering to the physiological state.

Methods

In 2014 and 2015 ballroom dancers from all around Poland, who were rehabilitated after injuries resulting from training ballroom dancing, were examined. As many as 63 athletes, survey showed, were injured during their career.

The questioned were professional dancers aged between 13 and 30 years old. In order to determine the influence of rehabilitation on dancers' health they were divided into two groups.

Table 2. Number of surveyed ballroom dancers, group I and II

Group	Number of dancers	
	n	%
I	47	75
II	16	25
Total	63	100

First group included 47 dancers whose rehabilitation took place in the rehabilitation centre under physiotherapeutic supervision. Second group consisted of 16 people who rehabilitated themselves on their own (Table 2). Statistical analysis showed no correlation between sex and age and link to particular group.

The opinion poll based on the survey was used as a test method. The questionnaire included closed and open questions which were to show the influence of injury and its treatment on future sports career. Questions were detailed and referred to kinds of injuries and their causes, the process of treatment, duration of rehabilitation, as well as its process and results.

The set of data was presented in graphs and tables. After collection of results the statistical analysis with the use of the Pearson's chi-squared test was conducted.

Test results and their analysis

Most of injuries happened during training (68%), no matter if the warm-up was in place or not. Nonetheless, there are not many dancers who will go training without a warm-up, but if such situation occurs, it is rather an incident than negligence. Next reason for sports injuries were long-term overloads (16%). Only 11% of the surveyed were injured during competition and only 5% during the warm-up (Table 3, Figure 1).

Table 3. Injuries in various situations of ballroom dancing

Injury circumstance	Numbers of injury	
	n	%
Warp-up	3	5
Training	43	68
Long-term overload	10	16
Competition	7	11
Total	63	100

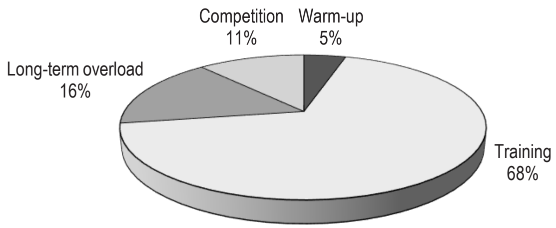

Figure 1. Injury circumstance

Lower limbs are the most prone to injuries in ballroom dancing, they constitute 47% of all injuries, spine injuries constitute 37% and upper limbs took the last place and were injured among 16% of the surveyed (Table 4, Figure 2).

Table 4. Various body parts injuries

Injured body parts	Number of injured dancers	
	n	%
Lower limbs	30	47
Upper limbs	10	16
Spine	23	37
Total	63	100

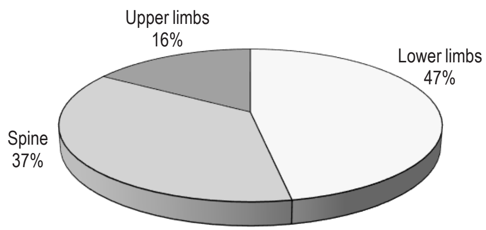

Figure 2. Injured body parts

The most frequent, among the most severe sports injuries, were muscle traumas (25%), rarely – bone traumas (22%), next – ligaments and tendons injuries (18% each), joint capsule injuries (12%). Other, which constituted 5%, were described as often not diagnosed or neurological (Table 5, Figure 3).

Table 5. Injuries of ballroom dancers

Tissues injured	Dancers' injuries	
	n	%
Muscles	16	25
Bones	14	22
Tendons	11	18
Ligaments	11	18
Joint capsule	8	12
Other	3	5
Total	63	100

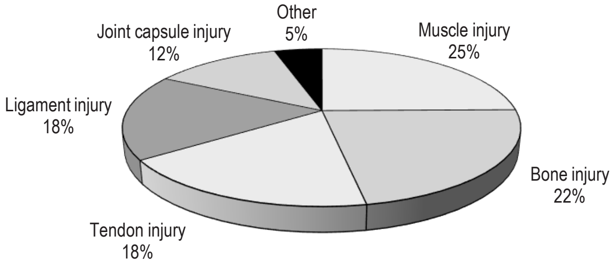

Figure 3. Tissues injured

Number of rehabilitation days varied according to the type of injury. Ligaments rehabilitation required the longest treatment. In the first group the average phase lasted 75 days and in the second as much as 120 days (Table 6). Such a considerable difference remained in each type of injury. Basing on this, it can be concluded that people not taking specialist treatment need more time to recuperate.

Table 6. Average number of days of rehabilitation of dancers after injuries

Type of injured tissues	Average number of rehabilitation days in particular group		Average number of rehabilitation days of all specific injuries
	I	II	
Muscles	14	30	22.0
Bones	35	56	45.5
Tendons	14	30	22.0
Ligaments	75	120	97.5
Joint capsule	21	28	24.5
Other	16	21	18.5

Unfortunately, seemingly small injuries are too often ignored and treated too long with the so called 'wellness' methods (Dziak, 2002). It leads to injuries being not fully treated and consequently – their frequent recurrence. Even 62,5% of self-treating dancers – often visiting charlatans who prey on their suffering – admit injury recurrence. In the group treated by specialists, only 15% suffered recurrence of ailments (Table 6).

The most frequent and common ways of coping with ailments include ointments and cryotherapy (Figure 4). Sportsmen often visit the masseur for help (some dance clubs have their own specialist, which facilitates and quickens the rehabilitation). Next, sportsmen employ physiotherapeutic treatments, take pharmaceuticals, and use kinesis therapy. When needed, the doctors use immobilisation and plaster casts. Fortunately, dancers rarely take steroids injections directly to joints, so called "blockages" which, in my opinion, act as a palliative only. Unluckily, there are cases when the operation is required. They refer mainly to spine and knee joint problems. Some of the surveyed supplemented the treatment with acupuncture, manual therapy, kinesio-taping, *etc.*

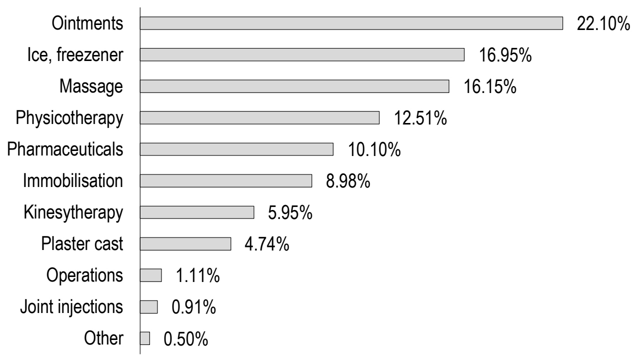

Figure 4. Methods of injury treatment

Often, quick restoration of the possibility of employing training and start loads from before the injury is impossible. Few self-rehabilitating people realise it. Complete recovery, before getting back on the floor, prevents severe injuries, which in ¼ cases originates from past problems (Table 7).

Table 7. Physical activity recovery of dancers after injuries

Physical activity recovery of dancers	Number of dancers in particular groups				Total	
	I		II			
	n	%	n	%	n	%
Complete	41	65	9	14	50	79
Partial	6	10	4	6	10	16
No recovery	0	0	3	5	3	5
Total	47	75	16	25	63	100

In the first group all dancers got back to the right physical activity. Only six dancers recovered partially, others recuperated completely. Unfortunately, in the second group not all of the sportsmen returned to the physical activity, what is worse, three of the surveyed lost the functions irrevocably (Figure 5). The statistical analysis, with the use of the Pearson's chi-squared test showed the significant correlation between the recovery of physical activity and the group division.

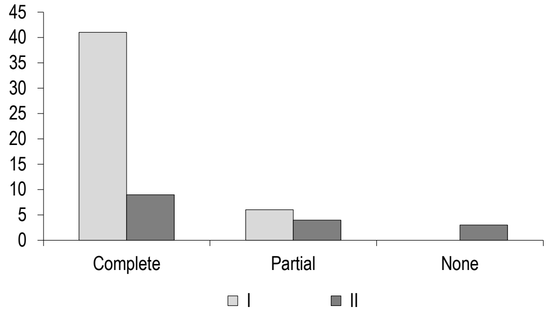

Figure 5. Level of physical activity recovery

Conclusion

1. Rehabilitation has positive influence on health of ballroom dancers after injuries.
2. Specialist rehabilitation shortens time of recuperation and boosts chances for complete recovery.
3. Physiotherapist rehabilitation at a good rehabilitation centre lowers the risk of reoccurrence of body injury of ballroom dancers.

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COMPARING THE EFFECT OF STATIC AND PNF STRETCHING ON HIP JOINT FLEXIBILITY OF UN-TRAINING FEMALE STUDENTS

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Abstract. Since many of people in their functional activities mostly place their knee joint in flexed position, the hamstring muscles tend to be shortened. On the other hand, shortness of these muscles affect the knee joint directly and the Hip Joint Flexibility indirectly. The purpose of this study is to compare the effect of static and PNF stretching on hip joint flexibility of un-training female students. Twenty-four 18–30 years old un-training female students without any history of pathology in hip, knee or back were selected. They were divided into three groups with 8 women in each group (static stretch, PNF stretch and control). The two stretch groups received stretching program three days every week for six weeks, while the control group did not. The result shows that range of hip joint flexibility of both groups of static and PNF stretching increased ($P < 0.05$). However, there was no significant difference between these two groups ($P > 0.05$). The while it remained unchanged in control subjects ($P > 0.05$). Employing both methods (static and PNF stretching) increase the hip joint flexibility. The findings of this study suggest that optimal flexibility is achieved with a combination of these two methods. Thus, we recommend the combined training method to athletes who require very high flexibility.

Key words: hip joint flexibility, static stretching, PNF stretching, student

Introduction

Flexibility is a very important duty and performance of human in order to achieve successfully his/her skills and abilities in a wide range of conditions. The high level of flexibility, adaptability not only introduces a factor in preventing injury but also causes a rapid movement to be performed easily and without any pressures. Thus, increasing flexibility is not only to meet the demands and needs of sport skills but it must be somewhat beyond the scope and the extent of the required maximum exercise (ability to create and develop flexibility storage) should be strengthened. The lack of flexibility may lead to failure and susceptibility to various disorders. Muscular flexibility is a major component of physical fitness and has long been the center of attention for athletes, champions, physical trainers, physiotherapists and rehabilitation professionals (Song, Seo, Shin, 2015). The results of this study show that the primary goal of flexibility is to increase the capacity of muscle fibers capable the elastic or stretching properties. The lack of sufficient activity to stimulate and maintain the readiness of the anti-gravity muscles and the use of muscles tensions doing the exercises of flexibility is necessary for some parts of the body; these parts include thigh, front hip, back, neck and chest (Blackhurst, Peterson, Herzog, Zimmerman, 2015; Song et al., 2015).

Stretching ligaments and muscles improve the range of motion in major joints of the body and the optimal muscle performance is the initial tension (McHugh Cosgrave, 2010)

The application of stretching exercise for improving flexibility is based on the notion that such exercise may reduce the occurrence, intensity and duration of muscular-ligamentous and articular injuries (Behm, Blazevich, Kay, McHugh, 2016).

Muscle flexibility is enhanced through various stretching exercises, including static, ballistic, proprioceptive neuromuscular facilitation (PNF) and vibration training. One example of PNF training is contraction-rest which some sources report to be superior to static stretching (Meliggas, Papadopoulos, Gissis, Zakas, Brabas, 2015). Another study, however, reported that 4 weeks of static stretching yielded better results compared to PNF (McGowan, Pyne, Thompson, Rattray, 2015). Some researchers have noted that vibration stretching methods are more efficacious for improving muscle flexibility (McGowan et al., 2015; Wagner et al., 2010). Funk, Swank, Mikla, Fagan, Farr (2003) compared the PNF stretching and static exercises on the hamstring flexibility. The results showed that PNF exercises made the maximum development of motion range in this regard (Funk, Swank, Mikla, Fagan, Farr, 2003). Jordan, Korgaokar, Farley, Caputo (2012) studied the long term effects of two types of PNF and static stretching on jumping performance and the range of motion. The results showed that stretching exercises caused an increase to the range of motion in both groups and also they did not affect the jumping scores (Jordan, Korgaokar, Farley, Caputo, 2012). The results of many studies have confirmed that static stretching methods and PNF muscular nerve facilitation had effect on the flexibility of hamstring muscles of non-dominant leg (knee active range of motion opening), but statistically there was no significant difference between the effect of static stretching and PNF methods on the flexibility of hamstring muscles of non- dominant leg (Jordan et al., 2012; Zarghami, Moghaddam, Hojjat, 2012).

Considering all these reports, there is no consensus regarding the optimal stretching exercise. Moreover, most studies have dealt with the mechanism of one or more stretching methods and have rarely considered the impact of comparing the effect of static and PNF stretching on hip joint flexibility. Thus, it is still uncertain which method will yield the optimal hip joint flexibility. The present study aims at comparing the effect of static and PNF stretching on hip joint flexibility of un-training female students.

Methods

Subjects

Twenty-four 18–30 years old un-training female through simple random sampling, were classified into 3 groups: static stretch (n = 8), PNF stretch (n = 8) and control (n = 8) groups. The subjects were female college students aged 18–30 years, and exercised at the Guilan University fitness center in Iran. All the subjects submitted a written consent form, and all the study procedures were approved by the Human Care and Use Committee of the Society of Sport Research Institute at Guilan University.

Experimental procedures

The two stretch groups received stretching program three days every week for six weeks, while the control group was not. The program was composed of 3 steps: warm-up, static stretch or PNF stretch and cool down. In the PNF group, the training consisted of 3 bouts of stretching per week: in each bout, the participant would rest the heel of her foot on a platform with his knee fully extended and then pushed the heel downwards isometrically to contract the posterior thigh muscles for 5 seconds. Then she would flex the waist to stretch the hamstring muscles for 30 seconds. In each bout, this exercise would be repeated three times for each leg (Zarghami et al., 2012).

Static Passive Hamstring Flexibility test

This test was performed in the supine position on an exercise bench. The functional knee brace was worn for testing. Passive stretching utilizes an external agent to assist with the stretch. The participant used a Velcro strap around the ankle to assist with pulling the limb into hip flexion. The dominant leg was flexed to the terminal ROM or until a mild discomfort/tightness was felt in the back of thigh (Meliggas et al., 2015). This position was maintained for five seconds following which the limb was slowly lowered to the resting position.

Statistical analyses

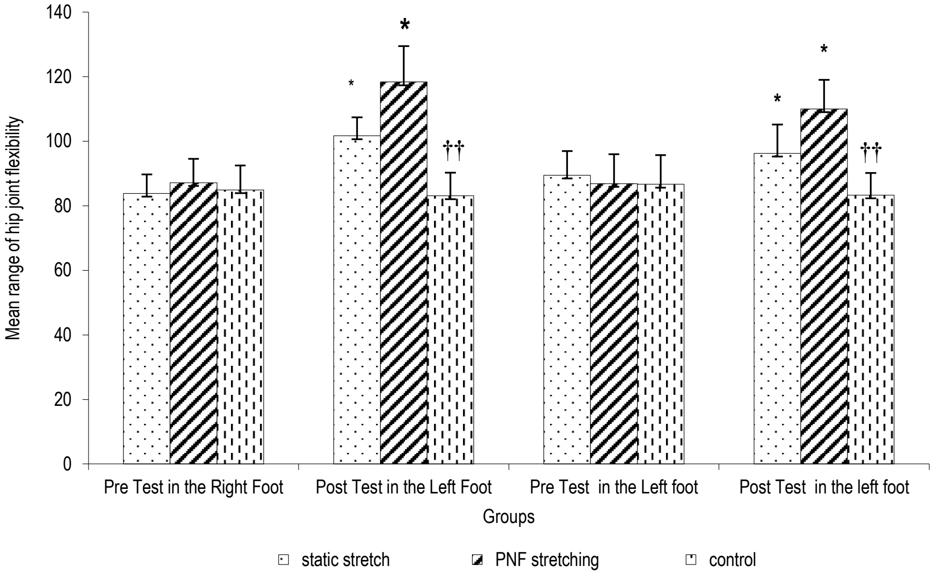
Descriptive statistics of range mean and standard deviation were computed on all the data. One-way ANOVA was calculated across all the groups over the 6 weeks of the study. A paired t-test was computed to compare the post intervention and carry over values. Level of significance was set at 0.05 Alphas.

Results

The subjects' characteristics did not significantly differ between the groups ($P > 0.05$) (Table 1). Figure 1 depicts the flexibility of the three static, PNF and control groups on pretest and posttest. As the figure illustrates, one-way analysis of variance indicated a significant difference between the three groups ($P = 0.001$). The results of post-hoc LSD test showed that this difference results from the difference between the PNF with control groups ($P = 0.001$), as well as between the static and control groups ($P = 0.004$); while it remained unchanged in control subjects ($P > 0.05$).

Table 1. Characteristics of the subjects (Mean ± SD)

Variables	Static Group	PNF Group	Control Group	P
Age, years	20.16 ±2.91	21.13 ±1.72	21.96 ±3.21	0.598
Height, cm	162.13 ±5.41	163.34 ±3.45	161.9 ±2.41	0.673
Weight, kg	60.21 ±6.60	59.29 ±4.60	57.33 ±7.19	0.389



* – significant difference between pretest and posttest; †† – significant difference from the combined group on posttest.

Figure 1. Flexibility of participants in the 3 groups on pretest and posttest

Discussion

Flexibility is an important physiological component of physical fitness, and reduced flexibility can cause inefficiency in the workplace and is also a risk factor for low back pain. This study focused on comparing the effect of static and PNF stretching on hip joint flexibility of un-training female students. The results of the study indicated that a period of 6 weeks of PNF and stretching exercises significantly increased the range of hip flexibility this way, thus, this method is considered as a desirable way to improve flexibility and muscle strength as well. On the other hand, this increase can be due to the rapid effect of muscular nervous mechanisms in deep- sense pathways of isometric stretching contractions.

Yuktasir, Kaya (2009) stated that in spite of increasing motion range followed by PNF methods, the activity of Electromyography in muscles is greater than static stretching method (Yuktasir Kaya, 2009). Blackhurst et al. (2015) reported that the static stretching of motion range is being double increases then dynamic stretching. Thus, due to a little discomfort of muscles with static stretching method, the tendency is high for applying the method preferably (Blackhurst et al., 2015). Lima et al. (2014) believe that the cause of most dynamic techniques effects is the increase of metabolite processes in which increases the temperature and decreases the muscle viscosity allowing the muscle slowly gets contracted. The warmed-up muscle is being arranged easily with the forces increasing the flexibility (Lima et al., 2014). Fasen et al. (2009) investigated the impact of 8 weeks of training with PNF, active and passive stretching to report that PNF and active stretching yield better knee range of motion while passive stretching yields better hamstring flexibility (Fasen et al., 2009). The impact of PNF and static stretching on muscle flexibility is mediated via neurophysiologic mechanisms, including the muscle stretch reflex (Miyahara, Naito, Ogura, Katamoto, Aoki, 2013; Place, Blum, Armand, Maffiuletti, Behm, 2013). These mechanisms increase the level of stretch endurance alongside improved muscle power and reduced pain sensation. Studies indicate that training aimed at improving neuromuscular control; including PNF and static training expedite flexibility and are more appropriate for treatment and rehabilitation of pelvic injuries compared to other stretching exercises (Place et al., 2013; Wicke, Gainey, Figueroa, 2014).

Other factors such as period of stretching, frequency of stretching and the age of people under study play key role in obtaining different results (Miyahara et al., 2013; Zarghami et al., 2012). According to the results of the researches and to prevent the effect of these intervening variables, all indices were equally selected for both groups.

In conclusion, although our findings confirm the positive impact of proprioceptive neuromuscular facilitation and static exercises alone on Hip Joint Flexibility, we recommend athletes (particularly those who require an excellent level of flexibility such as gymnasts, ballerinas, divers and wrestlers) to combine both exercises (PNF and static training) in order to achieve level of muscle relaxation and flexibility necessary for the complicated motions of their field.

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PHYSICAL ACTIVITY AS PREVENTION OF CHRONIC ILLNESSES IN SENIORS

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Abstract. Physical activity is of key importance in prevention of chronic illnesses, such as cardiovascular disease or metabolic diseases. Lack of regular workout in seniors favors the development of these diseases. It is, therefore, advisable to change one's lifestyle and engage in regular workout in order to reduce the risk of chronic illnesses and disabilities. The aim of this paper is to present how important physical activity is in prevention of chronic illnesses in seniors.

Key words: physical activity, seniors, chronic illnesses

Introduction

Among seniors, 65+-year-olds are the quickest growing age group. At the same time, this particular group suffers from the highest incidence of chronic illnesses, physical disabilities and dependence on health care, although majority of these cases might be effectively prevented (Borowiak, Kostka, 2006; Kurpas, Czech, Mroczek, 2012).

Approximately 88% of 65+-year-olds suffer from at least one chronic disease which in many cases decreases their well-being and comfort of everyday life (Makowiec-Dąbrowska, 2012). Although it has been proved that regular workout helps maintain good health and fitness, seniors tend to adopt more sedentary lifestyle over time. Majority of 65+ Social Services patients are individuals suffering from one of chronic illnesses or disabilities (Psaltopoulou et al., 2008).

It has been shown that workout leads to lower risk of ischemic heart disease, hypertension and type 2 diabetes (Forjasz, Nowak, 2015). It is justified to believe that this relation can be extended to seniors as well. In fact, given the higher incidence of these diseases, one may expect even better results. Intolerance of workout and lack of cooperation in seniors usually stem from a misconception that chronic illnesses are an intrinsic part of the aging process. It is commonly believed that seniors' lifestyle cannot be changed, that chronic illnesses cannot be prevented – just as the old age is unavoidable. Many studies, however, proved that these beliefs are not grounded (Rywik et al., 2001).

Today we know that some risk factors may be decreased, i.e. they are not unavoidable, as many would argue. In order to do that, a change of lifestyle and regular workout are recommended. Physically active seniors run lower risk of disability and present lower costs of health care (Pasek, Pasek, Sieroń, 2011).

The aim of this paper is to present how important physical activity is in prevention of chronic illnesses.

Workout vs cardiovascular disease

Sedentary lifestyle is an independent risk factor of cardiovascular disease. As a result, it leads to twice as many illnesses, compared to physically active individuals. Lack of exercise is just as risky for the circulatory system as smoking 20 cigarettes per day, high cholesterol or mild hypertension. Regular workout effectively prevents hypertension, type 2 diabetes and ischemic heart disease. Moreover, exercise is related to other lifestyle changes, such as lowered body mass and generally lead to improved quality of life (Bild et al., 1993).

With age, the incidence of obesity, glucose intolerance, ischemic heart disease, hypertension and fat metabolism disorders increases. Clinical trials with young and middle-aged men showed that increased physical activity leads to lowered total cholesterol, LDL and triglyceride levels, and well as decreased blood pressure. Workout increases HDL levels and overall fitness (May at al., 2006). Unfortunately, evidence of beneficial effects of workout on seniors are much more modest. Some researchers believe that achieving similar results in seniors requires longer but less intense workout (Fiatarone, O'Neill, Doyle, 1994; Gębka, Kędziora-Kornatowska, 2012).

In hypertension

Change of lifestyle, i.e. increased physical activity and low-fat diet results in lowered tension and overall improvement of lifestyle (Knoops, de Groot, Kromhout, Perrin, 2004). It is recommended to encourage all patients to change their lifestyle, which will lead to lowered tension and decreased risk of cardiovascular diseases. If there are no additional risk factors or permanent damage to organs, patients with mild or moderate hypertension are advised to change lifestyle as the only treatment in hypertension. Thus, pharmacotherapy may be delayed for one full year. It is advisable to attempt to control hypertension by changing patient's lifestyle instead of prescribing drugs (Leveille, Guralnik, Ferrucci, Langlois, 1999).

This disease requires a careful selection of exercises (Pasek et al., 2011). It has been shown that dynamic aerobic exercises (such as marching, running) decrease tension. Static exercise, however, seems less effective, therefore individuals who do static workout should be carefully monitored. Light or moderate dynamic workout (30 minutes, at least 3 times per week) lower tension much more effectively than more intense workout. This level of physical activity is also recommended by WHO (WHO 1997). Therefore, patients should be encouraged to engage in moderate, not intense, workout. As a result of exercises, blood pressure is lowered by 5–10 mm Hg in only 5 weeks. Moderate workout brings many health benefits, does not overstrain the patient, is safe and, most importantly – does not put off the patient, which promotes perseverance. For the beneficial effects to appear, the patient needs to exercise regularly and over a period of time. Light and moderate hypertension patients get better effects when they participate in dynamic, moderately intense workout for 60 minutes 3–4 times per week (Kurpas, Kusz, Jedynak, Mroczek, 2012).

Hypertension patients' reaction to workout program may vary, depending on level of hypertension, medication and age. The increased by exercise Vo2 max is not always accompanied by adequately lowered tension. Individuals who take blood pressure-reducing medication should also take up exercise as an additional measure. Regular workout sometimes reduces the need for medication. Even better results may be obtained by implementing exercise and other lifestyle changes and pharmacotherapy (Bild et al., 1993).

Significant reduction of blood pressure does not require very intense exercises. Patients should not be advised to perform only isometric and weight exercises, as it is still uncertain whether they have truly beneficial effects. It is known, however, that they result in a short-term increase of systolic and diastolic pressure. Individuals with well-controlled light or moderate hypertension may use weights during exercise. Naturally, these exercises should be closely monitored and the weights should not be too heavy, while number of repetitions in a series may be increased. Seniors should not exercise in hot environments due to their inefficient thermal regulation. Moreover, patients should be made aware that hypertension medication influences central or peripheral nervous system, which may lead to physiological response of the body, e.g. slower or faster heartbeat. Some drugs, especially beta-blockers, may lead to slower heartbeat, which requires increased stroke volume to meet higher oxygen needs of the muscles at work. These drugs may, therefore, lead to lowered stamina of the patient (Kostka, Bogus, 2007).

Heart failure

Not long ago, it was still believed that physical activity is not beneficial to convalescent patients with a significant left ventricle dysfunction (Marchewka, Dąbrowski, Żołądź, 2012). Patients with heart failure were therefore advised to rest. However, since 1980s it has been believed that aerobic exercises and exercises with small weights may be beneficial. They lead to increased stamina and breathing reserve, improved blood circulation in lower limbs and mitigation of symptoms.

Intensity and duration of workout depend on the severity of symptoms. It is recommended to take breaks every 5–10 minutes to avoid patient's discouragement, tiredness, injuries and complications of the circulatory system. Patients with heart failure (as opposed to patients with other circulatory system diseases) should engage more in exercises with weights (Kostka, Lacour, Bonnefoy, 2001). Many authors believe that this type of exercise is risky as it leads to a sudden and increased oxygen consumption of the heart and higher systolic blood pressure (Korewicki, 2000; Kurpas, 2012; Papademetriou, 2005). There are no established recommendations for exercises with weights. Majority of researchers agree that patients should start with 1–3 series of 12–15 repetitions of exercises that involve large muscle groups before they add exercises involving smaller muscle groups. While lifting weights, one should avoid the Valsalva effect (Makowiec-Dąbrowska, 2012).

Patients with congestive heart failure are advised to perform interval training. It encompasses 10–20 cycles: 30 seconds of intense aerobic exercise followed by 60 seconds of rest. Patients who have led sedentary life may at first need to reduce the 30-second period, as it may be beyond their abilities. They should not, however, give up the weights, as they are the trigger for type 2 myofibers (Sygit, 2015).

Exercise in metabolic diseases: fat metabolism disorders and diabetes

Majority of studies devoted to impact of exercise on fat metabolism disorders focus only on age groups with highest incidence (44–55 years old; observation ends with 65–70-years-olds). There are no studies available devoted to individuals over 70 years of age, as well as only women. The best documented issue is the impact of exercise on HDL concertation (Kostka, Bogus, 2007).

It has been proved beyond doubt that with age glucose intolerance and incidence of type 2 diabetes increases. There is no clear evidence, however, that these phenomena are related to lack of exercise. In diabetic patients, exercise has positive impact on circular system functions and insulin sensitivity, which in turns improves metabolic control. It often helps reduce the need for oral diabetes medicine. Changing one's lifestyle, e.g. taking up regular exercise, may even prevent development of type 2 diabetes (Kurpas et al., 2012; Gębka, Kędziora-Kornatowska, 2012).

In American research, 530 subjects with glucose intolerance were divided into 4 groups. Group I did exercise, Group II went on a diet, Group III did exercise and went on diet, while Group IV was the control group with no changes to their lifestyle. During the research (2002–2004) diabetes incidence in groups I–III was lower than in Group IV. The difference was proportional to intensity of preventive measures. It may mean that the bigger changes of lifestyle, the better chance of avoiding type 2 diabetes in old age (Di Bari, van de Poll-Franse, Onder, 2004).

Workout is a very effective, additional part of treatment of type 2 diabetes, especially in seniors. However, seniors should be given detailed instructions as to how to accompany the trainings with diet, liquids, how to control sugar concentration, what shoes to wear, how to warm up and how to finish the training. Podiatrist or sports trainer's advice may be required when choosing appropriate shoes. Sugar level fluctuations during training may be avoided by consuming energy bars and drinks at particular intervals (Sumukadas, Witham, Struthers, McMurdo, 2007).

Except for patients with complications, training plan modifications are hardly ever required for type 2 diabetes patients. Patients suffering from Buerger's disease, sensory neuropathy or advanced small fiber neuropathy should work out less intensely, avoid overstaining and wear special shoes. Workout plan needs to avoid body positions which affect the autonomic nervous system (e.g. sudden strain). Diabetes patients should not exercise in extreme temperatures. Individuals with fat metabolism disorders may work out without any particular limitations. Patients with diabetes and fat metabolism disorders who exercise are often able to reduce number of drugs or dosage. There are no confirmed effects of drugs on the training results. Individuals who suffer from muscle pain due to statin-based drugs, may experience increase in their symptoms as a result of exercise, especially intense workout. In such case, lowering intensity of work-out should help; another solution would be changing the drug(s) (May et al., 2006).

Exercise versus osteoarthritis

Seniors with osteoarthritis experience reduction in pain resulting from exercise. It also improves perception, strength, agility and stamina of the body. Thus, exercise has a positive impact on functional independence of patients (Kostka, Drygas, Jegier, Zaniewicz, 2009). Until not long ago, there had been no evidence of beneficial effect of exercise on osteoarthritis. On the contrary, authors of many retrospective studies noticed adverse effect of some occupational and sports therapies on the development of osteoarthritis. However, it has been found that incorrect planning of these studies makes their results unreliable (Sygit, 2015). Those studies' conclusions rather discourage from exercise. Meanwhile, workout is recommended by the American College of Rheumatology (Leveille et al., 1999).

A study that involved a small group of subjects showed that aerobic work-out and exercises that strengthen quadriceps femoris helped avoid pain and improve patients' fitness. In randomized study by Fiatarone et al. authors showed that seniors who did weight and aerobic exercise, experienced less pain after 18 months, and their general fitness was better compared to subjects who did not exercise, but took part in educational classes. During the study, subjects took their previously prescribed drugs, whose dosage and number was not changed. The assessment of results did not take these drugs into consideration (Fiatarone et al., 1994).

Pain plays significant role in patient's willingness to exercise. Moreover, joint instability caused by the illness or loss of protective tonus, strength and proprioception may increase the risk of injury or force the patient to reduce intensity of the training. In such cases, one needs to consider exercises done on suspensions, stretching training or higher number of series with lower number of repetitions (Pasek et al., 2011).

Training program should include both strength-building elements, as well as exercises increasing joints' range of motion. Further joint deformation must be avoided. Forced movement of deformed joints results in increased instability and pain. A reliable overstrain symptom is pain that persists more than 2 hours after the training. Knee osteoarthritis patients are often encouraged to work out at home, using progressive anaerobic exercise with limited strain of joints, as well as exercise that increases joint mobility (Pasek et. al., 2011; Rywik et al., 2001).

Exercise versus osteoporosis

As many as 30% of women after menopause suffer from osteoporosis. Knoops et al. assessed that excess mortality in this group is caused in 20% by consequences of broken femoral neck due to osteoporosis. Cumulated life-long risk of this type of injury for 50-year-old woman may amount to 60% (Borowiak, Kostka, 2004). The role of physical exercise in osteoporosis prevention is still argued. It has been recently stated that physical exercise helps prevent bone mass loss in lumbar spine, however, it does not affect calcium scores in the forearm and femur bone (Marchewka et al., 2012).

Incidence of broken bones in seniors has doubled in the last 30 years. Incidence of osteoporosis also increased, which translates into higher costs of health care and social services. If physical activity prevents bone mass loss, it may reduce the incidence of fractures (Psaltopoulou et al. 2008). W. Evans concluded that physical activity leads to lower risk of future fractures by 50% (Evans 1999). D. Bild et al. studied the relation between physical activity and risk of future fractures due to osteoporosis in 704 women aged 65+. The study lasted for 7 years. Amongst very active subjects, the incidence of femoral neck fracture was 36% lower than amongst the least active individuals. There was no difference, however, in terms of broken epiphysis of radial bone and bodies of vertebrae. Authors concluded that the beneficial effect of exercise on femoral neck fracture must have more than one mechanism. Probably, the risk of femoral neck fracture among low-activity individuals is lower that among those who are not active at all (Bild et al., 1993).

Prevention of seniors falling down

For the elderly, falling down is a symptom of aging, which causes fear of injury and loosing independence. Majority of falls are caused by a combination of external and internal factors, therefore the risk of falling down should always be assessed in terms of the body and the environment.

Consequences of falling down for seniors are commonly known. Fractures of femoral neck, scull and soft tissues injuries not only cause a great deal of suffering, but also require long and costly treatment and rehabilitation. Fractured femoral neck is a special threat to patients and their families, as it results in loss of independence. Walk instability and falling down are common reasons for placing patients in nursing homes. The fear of fall itself is capable of limiting one's physical activity, causing social isolation, depression, weakened muscles, worsened physical fitness (Makowiec-Dąbrowska, 2012).

Incidence of falls and injuries

Falls were observed most commonly in individuals who took sedatives, those with impaired cognitive skills, walk and balance disorders, disabled due to lower limbs and foot diseases. Approximately 50% of falls may be attributed to risky activities or external factors, while only 10% to acute illnesses. As authors report, among subjects who had fell down, every fourth person suffered from severe injury, especially to soft tissue. Probability of falling down is higher for women, individuals with low body mass and with limited cognitive skills. Nursing home patients face the risk factors frequently. The incidence of falling down is three time higher than in population of seniors who live at home. Thus, it is not surprising to see that fractures due to falling down are a common problem (Tinetti, 1986).

Naturally, not all seniors are equally susceptible to falling down. According to various studies, the highest risk is faced by those individuals who often experienced injuries. Based on number and type of falls, we may select patients who need complex studies. Various disease-triggered and aging-related changes may disrupt nervous system functions: sensory, central and motor, which are essential in maintaining walk stability (Pasek et al., 2011).

Single fall does not need to prove an onset of locomotive problems. It takes many disordered functions to cause problems for seniors.

A classic medical check-up, involving an assessment of organ and system functions, usually lets the doctor determine states which hinder transmission of visual and sensory stimuli, slow central processing of information, limit motor functions and weaken fitness level.

Occupational therapist may be of great help in day-to-day life of seniors. They can teach their patients how to safely care for themselves and perform necessary actions. The doctor should know whether the patient is afraid of falling down, displays symptoms of depression or has personal problems. Environmental circumstances are just as important as clinical problems (Kurpas et al., 2012; Sygit, 2015).

Conclusions

One of the most important factors that ease the passing of time and help seniors 'age well' is regular physical exercise (Kulik, Janiszewska, Piróg, 2011). Sedentary lifestyle, common in seniors, has adverse effect on majority of systems and functions of the body, which are necessary to maintain independence in everyday life. Inactivity leads to worse functions of circular, respiratory and motor systems and results in lower fitness level. Additionally, inactivity hinders glucose and orthostatic tolerance, interferes with mineral metabolism and results in many negative changes in the human body (Makowiec-Dąbrowska, 2012).

In the past decades, patients suffering from various diseases were recommended to avoid exercise. Now it is known that negative consequences of hypokinesis are usually much worse than the effects of the disease itself. Thus, physical activity may be now treated as common denominator of all preventive and rehabilitative actions, irrespectively of health and fitness levels of seniors (Marchewka et al., 2012).

Recommendations for seniors include disability prevention, as well as prevention of disease typical of seniors (osteoporosis), while they still include advice for younger generations – preventive function of physical activity against circulatory and metabolic diseases (Kulik et al., 2011).

Regular physical activity, counteracting the effects of hypokinesis, has a number of beneficial effects for seniors. It is a universal medicine used in prevention and treatment of age-related illnesses (ischemic heart disease, hypertension, obesity, hypercholesterolemia, diabetes, osteoporosis). Physical activity leads to better insulin sensitivity, improved glucose tolerance and lower risk of developing diabetes. Regular physical activity in seniors results in lower incidence of infections and normalizes lipid values (Psaltopoulou et al., 2008; Rowe, Kahn, 1997).

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INFLUENCE OF SELENIUM ON OXIDATIVE STRESS IN ATHLETES. REVIEW ARTICLE

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Abstract. The aim of the study was to analyze the influence of selenium (Se) on the course of oxidative stress in trained athletes, on the basis of own former published studies and the reference of literature. In a number of references it was shown that the application of Se led to the diminishing of oxidative stress during the physical exercises in athletes. The application of Se to athletes − led to the increase of peroxidase glutathione the main selen − dependent enzyme. The fact of increased concentration of malondialdehyde (MDA) in blood serum, the main metabolite of lipid peroxidation can indirectly evidence about the intensity of physical endurance. This increase is significantly smaller in individuals taking exogenous antioxidative diet supplement containing Se. Moreover there is the evidence that oxidative muscles damage during physical effort could be diminished by compounds with antioxidative properties. Taking into consideration, the obtained results by many of authors empower to the conclusion that application of Se diminishes the degree of peroxidation of lipids in trained athletes.

Key words: selenium, gluthatione peroxidase, malondialdehyde, athletes, physical exercise

Introduction

Due to its significant biological functions, as well as slight diversity between the dose essential for proper functioning of the organism and its toxic dosage, during recent years selenium concentration constituted a subject of considerable interest as far as toxicology specialists and researchers from other branches are concerned (Sieja,Talerczyk, 2004; Zyska, Ślęzak, 2007; Puzanowska-Tarasiewicz, Kuźnicka, Tarasiewicz, 2009; Lippman et al., 2011).

Until now it has been documented that the strained physical exercise causes the increased production of free radicals. This process brings into the changes of oxidative state of the cells during short-term effort, as well as in long-term adaptation to physical exercises. (Savory et al., 2012; Kaczmarski, Wójcicki, Samochowiec, Dutkiewicz, Sych, 1999).

The aim of this study is the presentation of the influence of selenium (Se) on the cause of oxidative stress in athletes on the basis of review.

Depending on the quantity of Se given there are changes of gluthatione peroxidase. This enzyme is increasing with the increase of Se ingestion (Rokitzki, Logemann, Keul, 1993). Besides this, Se is incorporated into other compounds having significance in the antioxidative processes such as selenocysteine and selenomethionine. It was shown that the increase in the amount of ingested Se leads to the increase of synthesis of biological active compounds containing Se, which assures peroxidation of lipids caused by free radicals (Sieja, Talerczyk, 2004; Drozda, Trzciński, Rutkowski,Grzegorczyj, 2008).

The most of reports as safe and adequate for people consider the doses of this microelement recommended by The Food and Nutrition Board of the National Research Council proposed in 1980 amounted to from 50 to 200 µg per day (Table 1).

Table 1. Safe and adequate amounts of Se ingested in diet (according to: National Research Council: Recommended dietary allowances 9 th revised ed., Washington D.C. Natl. Acad. Sci., 1980)

	Age (y.)	Recommended amount of ingested Se (µg/per day)
Infants	0.0–0.5	10−40
	0.5–1.0	20−60
Children	1−3	20−80
	4−6	30−120
	7−11	50−200
Adults		50–200

Discussion

According to Dróżdż, Tomala, Jędryczka (1989) the normal concentration of Se in blood serum of adult in Poland should be 125±18 ng/mL . In Table 2 the concentrations of Se in blood serum in adults in Poland according to different authors are presented (Wąsowicz, Gromadzińska, Rydzyński, 2003; Łabędzka, 1991; Zachara, Wąsowicz, Gromadzińska, 1995; Kłapcińska, Poprzecki, Danch, 2005; Kapka, Baumgartner, Siwińska, 2007). As it results from this table this concentration is below the optimal value (Gać, Pawlas, 2011).

Table 2. The concentration of Se in blood serum in healthy adult persons in Poland according to different authors

Region of Poland	The concentration of Se in blood serum (ng/mL)	Authors
Pomerania	73.7 ±15.4	Łabędzka, 1991
Pomerania	52.0	Zachara et al., 1985
District of Łódź	50.0–55.0	Wąsowicz et al., 2003
Upper Silesia	63.5 ±18.1	Kłapcińska et al., 2005
District of Lublin	51.0 ±8.26	Kapka et al., 2007

The other antioxidant taking part in the protection of cells from free radicals is vitamin E. It was shown that oxidative damage of many tissues is greater in the case of deficiency of both of these compounds. Lee, Csalhany (1994), Kaczmarski et al. (1999) gave young men diet supplement Protecton Zell Activ (Smith Kline Beecham) containing in one capsule Se (25 μg) and vitamin E (18 mg), and moreover 100 mg vitamin C, 22 mg niacini, 7.5 mg β-caroten and 2.25 mg witamine B_2 two-times per day orally after eating for one month. Before and after the physical exercises during one month the concentration of Se in blood serum was determined.

The application of the above-mentioned drug caused significant increase of Se concentration in serum from 55.55 ±21.62 to 92.60 ±11.61 μg/dl ($p < 0.001$). The muscles condition was monitored by the activity of lactate dehydrogenase and creatinie kinase in serum. Simultaneously significant decrease of activity of lactate dehydrogenase and creatinine kinase was found. Davies, Qintanilha, Brooks, Packer (1982) revealed that the intense physical exercise very often causes the damage of muscle and the loss of their normal activity. Thus, it can contributed to damaging action of free radicals. In the course of physical effort excessive peroxidation of lipids took place (Viguie et al., 1993; Rokitzki et al., 1993).

The comparison of the activity phosphocreatinie kinase in rest before and after the therapy with „Protecton Zell Activ" revealed significant decrease of this activity following taking this drug. The above-mentioned diet supplement could probably have favourable influence on the metabolism of muscle tissue, thus causing the decrease in resting concentration of phosphocreatine kinase in serum.

The fact of increased concentration of malondialdehyde (MDA) in blood serum, the main metabolite of lipid peroxidation can indirectly evidence about the intensity of physical endurance.This increase is significantly smaller in individuals taking above-mentioned exogenous antioxidative diet supplement.

It proved the protective influence of Se on lipid peroxidation and thus on its antioxidative effect (Łabędzka 1991). Davies, Qintanilha, Brooks, Packer L. (1982), Kaczmarski et al. (1999) and Clarkson, Thomson (2000) have shown that physical endurance increases the concentration of free radicals and the quantity of arising malondialdehyde (MDA). A number of authors have shown that with the degree of intensification of physical strength the concentration of MDA in overstretched muscles increases. However, the increase of training is the cause of diminishing concentration of MDA in blood serum (Alessio, Goldfarb, Cutler, 1988; Kaczmarski et al., 1999; Rokitzki et al., 1993). Kaczmarski et al. (1999) studies revealed that the application of medication „Protecton Zell Activ" − diet supplement − which main compound was Se, led to diminishing oxidative stress, not only in the course of physical effort but simultaneously it was the cause of diminishing of the grade of lipid peroxidation – during long-term application in healthy individuals. Moreover, the study of Sieja, Talerczyk (2004) has also shown the decreasing of oxidative stress after the application of the above-mentioned diet supplement in women with ovarian cancer undergoing chemotherapy. Selenium and zinc supplementation may improve general clinical course in patients with cancer of digestive tract (Federico, Lodice, Derl Rio, Mellone, 2001; Wojtczak, 2003).

The increase of malondialdehyde (MDA) indirectly indicate about oxidative status evoked by physical exercise. The application of Se during training causes the significant increase of glutathione peroxidase activity and hence the increase of antioxidative barriers (Kaczmarski et al., 1999; Savory et al., 2012; Clarkson, Thompson, 2000). Antioxidants such as Se, vitamin E, vitamin C in trained individuals favourably affect free radicals metabolism determined by the concentration of malondialdehyde (MDA) in blood serum. The application of "Protecton Zell Active" diet supplement led to the increase of antioxidative potential of the organism determined by the concentration of malondialdehyde (MDA) in blood serum. (Kaczmarski, 1998).

One month application of „Protecton Zell Aktiv" – diet supplement – caused significant increase of Se concentration in blood serum. It must be underlined that after discontinuation of this diet supplement, after the period of one month the concentration of Se is lowering to values similar to these observed before the application of Se (Sieja, Talerczyk, 2004).

The above-mentioned clinical results were affirmed by experimental results on rats. The results of study of Akil et al. (2015) indicate that acute swimming exercises in rats cause lipid peroxidation in liver and lung tissues while Se administration prevents free radical formation by increasing antioxidant activity.

Savoy et al. (2012) have shown that both obesity, as well as acute high-intensity exercise increase oxidant stress levels, the study of the above-mentioned authors revealed that Se supplementation could be a potentially effective therapy to reduce obesity-associated oxidant stress and exercise-induced oxidant stress. This study has highlighted a potential benefit of Se in reducing LH (lipid peroxide) levels postexercise in overweight individuals. Given that oxidant stress is a predictor of coronary events, it is imperative to better understand oxidant-related responses to life-style (in particular in "high-risk" population groups) and potential antioxidant therapy (Fredrikson et al., 2004).

Physical exercises appear to increase reactive forms of oxygen, which could led to damage of the cells. Physical exercises lead to the increase of MDA concentration in blood serum. The concentration of MDA serves as indirect index of lipid peroxidation (Carkson,Thompson, 2000). Physical training seems to reduce oxidative stress of exercises. Trained athletes who received antioxidant supplements show evidence of reduced oxidative stress and increase of immune defence system compared to untrained individuals (Clarkson, Thompson, 2000; Döker et al., 2014).

Currently, more and more convincing evidence that oxidative muscles damage during physical effort could be diminished by compounds with antioxidative properties has been obtained. Theoretically, systematically trained physical exercise could demand adequate antioxidant supplementation. Until now the results of studies fully confirm that long-time application of antioxidants is safe and effective. Thoughtful recommendation for physically active individuals is consuming diet rich in antioxidants including Se (Fredrickson et al., 2004; Margarits et al., 2005).

Trained athletes who obtain antioxidants reduced oxidative stress (Margaritis et al., 2005). On this basis many of trained athletes are taking diet supplements with antioxidative compounds. Until now the influence of antioxidants on physical effort induced by oxidative stress in individuals undertaking sporadically intensive physical exercise is not fully explained. Pograjc, Stibilj, Falnoga (2012) did not found favourable influence of exogenous antioxidants in the course of oxidative stress evoking short-term physical effort in untrained individuals.

Taking into consideration the results obtained by many of the authors (Akil et al., 2015; Lee, Csalhany, 1994; Margarits et al., 2005; Kaczmarski, 1999; Sieja, Talerczyk, 2004) we are empowered to the conclusion that application of Se diminishes the degree of peroxidation of lipids in trained athletes.

Conclusions

1. Application of selenium diminishes the degree of peroxidation of lipids in trained athletes.
2. Long-time application of antioxidants is safe and effective.

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WHAT DOES POST-EXERCISE PROTEINURIA TELL US ABOUT KIDNEYS?

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Abstract. **Objectives**. Post exercise proteinuria (PEP) is found in about 20–40% of sportsmen after intensive exercise. Urinary NGAL is a new marker of tubulointerstitial kidney damage. The relationship between PEP and uNGAL has not been defined yet. In presented study a resting uNGAL as a predictor of PEP was analyzed. The changes of albuminuria after exercise were monitored to estimate a frequency and range of PEP. **Methods**. 40 amateur healthy runners (mean age 36.65 ±10.61 years) participating in 10-km run took part in the study. Before and after the competition urine was collected. NGAL, albumin and creatinine were subsequently measured in urine. uNGAL to creatinine ratio (NCR) and albumin to creatinine ratio (ACR) were calculated. **Results.** 28 participants (mean age 37.9 ±11.46, 19 M, 9 F) with uNGAL below 15 ng/ml before competition were analyzed. The increase of ACR was observed in every case. Mean post-exercise ACR was 104.55 ±123.1 mg/g and was significantly higher than pre-exercise ACR 6.33 ±5.86 mg/g ($p < 0.0005$). The positive correlation was found between resting NCR and post-exercise ACR ($r = 0.60$, $p < 0.05$). **Conclusions**. Resting uNGAL positively correlated with PEP. The possible explanation of these findings is that persons with PEP had some early, occult tubulointersitial kidney damage. It is speculated that those runners have higher risk of chronic kidney disease.

Key words: chronic kidney disease, albuminuria, health, running

Introduction

The kidneys play a pivotal role in the fluid and acid-base homeostasis of the human body (Curthoys, Moe, 2014). Due to renin and erythropoietin production and secretion, they regulate arterial blood pressure and hemoglobin levels, respectively. It is hard to imagine proper physical activity without normal kidney function. Indeed, fatigue and muscular weakness are the commonest symptoms of renal failure. (Bello, Kawar, El Kossi, El Nahas, 2010). During intensive exercise the kidneys struggle against dehydration and acidosis. Of prime importance is the proximal tubule, which contributes to fluid homeostasis by the reabsorption of water and solutes. The proximal tubule is also a metabolic organ and plays an important role in gluconeogenesis, a process in which lactate is consumed and glucose is produced (Curthoys, Moe, 2014).

The kidneys experience some significant changes caused by high-intensity physical activity. During exercise a decrease in renal blood flow of up to 30–40% is observed (Junglee et al., 2012).

It is not surprising that some abnormalities in laboratory tests are found after exercise. Some of these, like post-exercise proteinuria (PEP), are thought to be physiological (Poortmans, Blommaert, Baptista, De Broe, Nouwen, 1997).

In the minority of sportsmen who have undertaken strenuous exercise, the glomerular filtration rate (GFR) decreases and consequently the creatinine level in the blood is increased. When this rise exceeds 0.3mg/dl, acute kidney injury (AKI) is diagnosed (Junglee et al., 2013) (Poortmans, Gulbis, De Bruyn, Baudry, Carpentier, 2013). A rise in "new markers of AKI", such as neutrophil gelatinase-associated lipocalin (NGAL) was also found after physical exercise (Lippi et al., 2012). According to the literature, PEP reflects only functional changes (Poortmans, 1985). An increase in NGAL is observed in tubulointerstitial damage. Therefore, it is not clear whether any correlation between PEP and NGAL exists. This was studied only once and no correlation between PEP and post-exercise NGAL was found (Junglee et al., 2012). Urinary NGAL is a predictor of AKI and the progression of chronic kidney disease (CKD). In this study, we measured resting urinary NGAL in healthy persons and analyzed whether this marker can serve as a predictor of PEP.

Methods

The study population consists of 40 amateur runners (22 males (M) and 18 females (F)), who ran 10 km road race. The runners were approached via local amateur sports club between February and March 2013. All participants were healthy, active adults (mean age 36.65 ±10.61 years), without kidney disease, hypertension or diabetes. Runners taking medicines, especially non-steroidal anti-inflammatory drugs, were excluded.

Exercise protocol

The study involved the collection of urine samples before and after the 10km road race. The 10 km races organized in Gdynia are among the most popular and prestige races in the Pomerania region and the study was performed during these events because they are a good occasion for participants to obtain season's or personal best results.

Biochemical analyses

Urine was collected within 30 minutes of starting the run (a sample at rest) and within 30 minutes after the event (an exercise sample). Samples for the measurement of albumin and creatinine were analyzed immediately. Samples for the measurement of urinary NGAL were frozen immediately and stored at –20˚C. The samples were frozen for six months before analysis.

Measurement of urinary albumin, creatinine and lipocalin-2/NGAL

Urinary albumin was measured by an immunoturbidimetric assay (ALBT2, Roche Diagnostics GmbHMannheim for USA). Urinary creatinine was measured by a kinetic colorimetric assay (CREA, Roche Diagnostics GmbHMannheim for USA). Urine concentrations of human lipocalin-2/NGAL were measured using the ELISA method (Quantikine High Sensitivity Human by R&D Systems, Minneapolis, Minn., USA), according to the manufacturer's protocol. Read absorbance measurements were made using a plate reader ChroMate 4,300 USA at a wavelength of λ = 450 nm. Minimum detectable concentrations were determined by the manufacturer as 0.012 ng/ml. The intra- and inter-assay coefficients for NAGL were 4.4% and 5.6%.

ACR and NCR calculations

The albumin-to-creatinine ratio (ACR, mg/g) and uNGAL-to-creatinine ratio (NCR, µg/g) were calculated. The definitions of albuminuria are shown in Table 1 (Mattix, Hsu, Shaykevich, Curhan, 2002).

Table 1. Definitions of albuminuria (Mattix et al., 2001)

	Spot urine		
	Albumin mg/l	sex	ACR mg/g
Normal albuminuria (formerly normoalbuminuria)	<20	M	<17
		F	<25
High albuminuria (formerly microalbuminuria)	20–200	M	17–250
		F	25–355
Very high albuminuria (formerly macroalbuminuria)	>200	M	>250
		F	>355

Abbreviations. ACR - albumin to creatinine ratio (mg/g) , M – male, F – female.

The normal values for NCR are not established.

Statistical analysis

We used Statistica 10 software (StatSoft, Poland) for the analysis. As the Shapiro-Wilk test showed that the distributions of ACR and NCR were significantly different from normal ($p < 0.05$), we used a non-parametric Mann-Whitney test and Spearman's rank correlation test for the statistical analysis. A p-value < 0.05 was considered statistically significant.

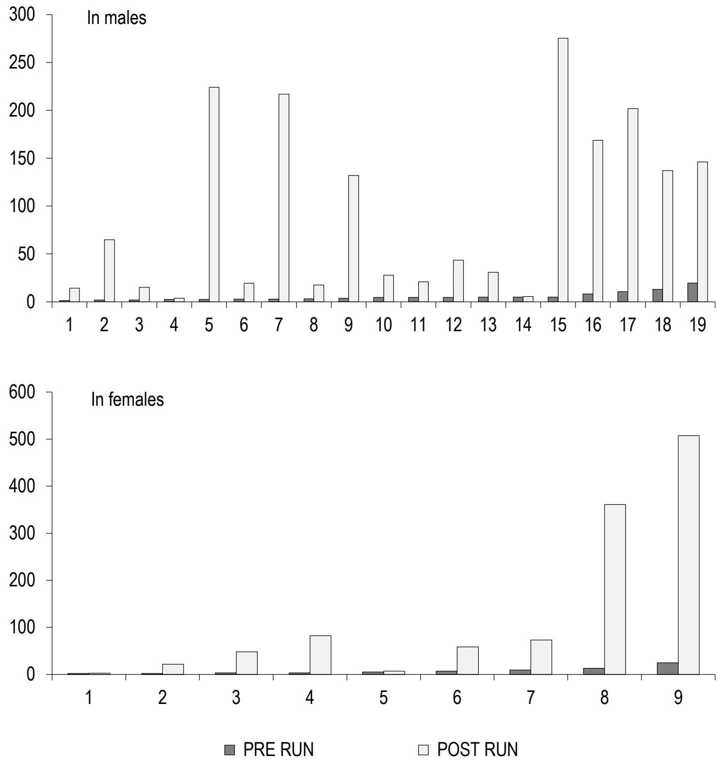
Ethics

The authors declare that the experiments reported in the manuscript were performed in accordance with the ethical standards of the Helsinki Declaration. All participants provided written consent and ethical approval was provided by the Medical University of Gdansk ethics committee (approval nr NKBBN/171/2013).

Results

The aim of the study was to examine if uNGAL in healthy persons is a predictor of PEP. uNGAL indicates tubular kidney damage and also neutrophil activation (Helmersson-Karlqvist et al., 2013). Therefore, only the runners with a resting uNGAL of below 15ng/ml were analyzed to exclude persons with an occult infection. 28 runners (19 males, 9 females), mean age mean age 37.9 ±11.46 years were analyzed. Pre-exercise ACR was normal in everyone (mean 6.33 ±5.86, range 1.22–24.6 mg/g). An increase in ACR was observed in every case to mean 104.55 (±123.1

mg/g). This increase was statistically significant ($p < 0.0005$). The range of post-exercise ACR was very wide from 2.89 to 507.11 mg/g. The increase in ACR varied from 1.15 to 83.49 (mean 18.3 ±20.91) fold (see Figure 1).



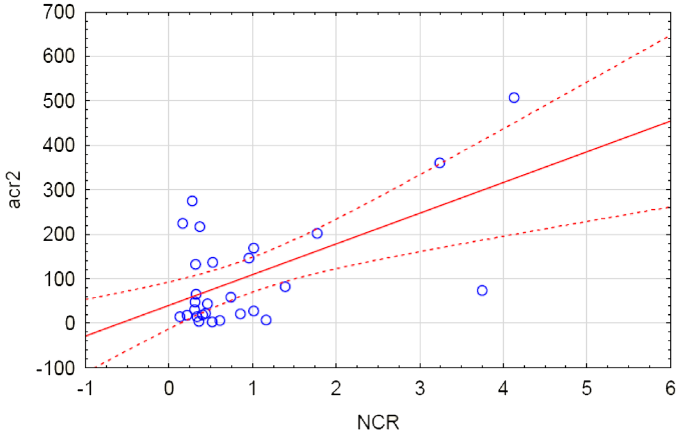
Abbreviations. ACR – albumin to creatinine ratio (mg/g).

Figure 1. The pre- and post-exercise ACR in males and females

After the competition, 21 runners had high or very high albuminuria (see Figure 1). The mean resting uNGAL was 6.03 ±2.99 ng/ml (range 1.67–11.89), and resting NCR 0.93 ±1.06 µg/g (range 0.13–4.13).

Resting ACR correlated positively with resting NCR ($r = 0.68$, $p < 0.05$) and a post-exercise ACR ($r = 0.67$, $p < 0.05$). A positive correlation was found between resting NCR and post-exercise ACR ($r = 0.60$, $p < 0.05$) (Figure 2).

There was no correlation between post-exercise ACR and BMI. There was no correlation between post-exercise ACR and age. There were no significant differences between the sexes. The runners with very higher albuminuria obtained better results in the race, but without statistical significance.



95% confidence level.

Figure 2. The correlation between resting NCR and post-exercise ACR

Discussion

A post-exercise rise of albuminuria was expected in this study and was observed in every case (Figure 1). It gave us the confidence that the intensity and duration of exercise was chosen well and the method of estimating PEP was sensitive enough to find even slight changes in protein loss. After exercise, ACR increased 18.3 times. There was a great variability in the ACR increase between participants (Figure 1). This prompted a question about factors causing such huge differences. The main aim of this study was to analyze uNGAL at rest as a predictor of PEP. Post-exercise uNGAL was not analyzed because a significant increase in uNGAL after a 10 km run was not expected. In previous studies, a rise in uNGAL was observed only after strenuous exercise (Lippi et al., 2012).

In this study the resting urinary NGAL-to-creatinine ratio correlated positively with resting albuminuria (ACR). This was not surprising because both are risk factors for nephropathies and cardiovascular diseases (CVD) (Helmersson-Karlqvist et al., 2013; Abdallah et al., 2013; Hasegawa et al., 2015). Resting NCR also correlated positively with post-exercise albuminuria. In other words, a marker of tubulointerstitial damage (uNGAL) predicts a physiological condition – PEP. This prompted another question: Is it possible that PEP is a kind of "kidney stress test" and unmasks some very early kidney damage?

In healthy persons, the kidneys filter approximately 180 liters of plasma containing 7.2 kg of albumin every day and over 99.999% of albumin is retained by the combined action of selective filtration and tubular reuptake (Johnstone, Holzman, 2006). In the rest, only 5–10 mg of the 7,200,000 mg of albumin flowing in plasma through the kidneys is lost in urine. In healthy humans, no protein is observed in a routine dipstick examination of urine. Proteinuria is one of the most common findings after exercise. It was first reported in urine studies of Boston marathon runners in 1941 (McCullough et al., 2011). and the increase in albumin excretion after exercise was first described in 1978 (Viberti, Jarrett, McCartney, Keen, 1978). Exercise is known to be the most common factor affecting albuminuria, alongside fever (Miller et al., 2009). PEP is a common finding and occurs in 20–30% of sportspeople. The frequency of PEP depends on the type of exercise and the method of estimation. In several classic papers by Poortmans (Poortmans et al.,1997), it was revealed that PEP is related to the absolute intensity of exercise. Poortmans speculated that PEP is caused mainly by enhanced glomerular membrane permeability, because albumin was the main protein lost during exercise (Poortmans et al., 1997). However, why this "physiological" proteinuria occurs and why it varies greatly between healthy persons was not fully established. Hemodynamic changes in kidney vessels was put forward as an explanation, because during exercise renal blood flow and hydrostatic pressure in glomeruli are increased.

In recent years our understanding of the pathology of proteinuria has changed. In a "classical" model of kidney function, virtually no protein was filtered through glomerular membrane, except for a scarce amount of low-molecular-weight proteins (LMWP). The increase in LWMP excretion was thought to be typical for tubule dysfunction and albuminuria for glomerular dysfunction. It is now known that a huge nephrotic-range amount of albumin is filtered in glomeruli and it is only because of the tubular function that this protein is not observed in urine Russo et al. (2007) showed that renal albumin filtration is 50 times greater than previously measured. This means that the proximal tubule is essential to prevent nephrotic range proteinuria (Russo et al., 2007).

It is possible that PEP is caused by tubular dysfunction. We know that albumin is reabsorbed mainly in the proximal tubule, and this tubule has some functions which are crucial in exercise (such as gluconeogenesis, acid-base homeostasis, reabsorption of water and sodium) (Curthoys, Moe, 2014). We may speculate that during exercise tubules have other important functions and are not trying to reabsorb albumin. During short-term exercise, it is better for the organism to regulate the water and electrolyte balance than to reabsorb every albumin from the filtrate.

This "tubular theory" of PEP might also explain the huge difference in the range of PEP in runners (Figure 1). Such a difference could not be explained by an increase in hydrostatic pressure in the glomerular vessels because blood flow could not differ so greatly between healthy persons. On the other hand, it is possible that exercise somehow "switches off" tubular reabsorption of albumin and at one moment, albuminuria can rise from the minimal to nephrotic range.

There is increasing interest in so-called new markers of AKI (Vanmassenhove, Vanholder, Nagler, Van Biesen, 2013).They help in an early diagnosis of AKI, but also are predictors of CKD progression and CVD events (Helmersson-Karlqvist et al., 2013; Abdallah et al., 2013; Hasegawa et al., 2015). One of the most commonly used is NGAL (Hasegawa et al., 2015). NGAL is a member of the lipocalin protein family that is produced in epithelial cells and neutrophils (Wu et al., 2013).This early marker of tubulointerstitial injury is used in clinical practice as well as in experimental studies. It identifies renal damage rather than renal dysfunction (Singer et al., 2013). So far, there have only been very few studies concerning the usefulness of new markers of AKI in exercise. In a large study of 425 runners, AKI was diagnosed in approximately 40% of marathon runners on the basis of elevated creatinine serum level (a rise of Cr $\geq$ 0.3mg/dl). In the same group, significant elevation of urine uNGAL was observed (McCullough et al., 2011). uNGAL and serum NGAL increased after a 60-minute downhill, muscle-damaging run (Junglee et al., 2012; Junglee et al., 2013). In another study, uNGAL increased 7.7-fold after a 60-kilometer ultramarathon (Lippi et al., 2012).

Unlike albuminuria, which seems to be a marker of intensive exercise, new markers of AKI are typical for long, exhausting exercise. However, uNGAL as a predictor of PEP has not yet been studied. Although increased albuminuria in rest is a predictor of renal and CVD events, the post-exercise increase in albuminuria is thought to be a physiological phenomenon. One fascinating possibility is that this benign condition occurring during exercise can unmask some diseases at their early, treatable stages.

ACR significantly increases in diabetics after exercise (Vanmassenhove et al., 2013), so it was suggested that post-exercise albuminuria unmasks early stages of diabetic nephropathy (DN) (Vanmassenhove et al., 2013; Di Paolo et al., 2007; Kim et al., 2012). The importance of PEP in patients with newly diagnosed type 1 diabetes is not established (Zmysłowska et al., 2007), but yet values are significantly higher in uncontrolled diabetes compared to those with good metabolic control (Agarwal, Thanvi, Vachhani, Kochar, Rastogi, 1998).

Conclusions

In the healthy population studied, both resting ACR and uNGAL were within normal values. There was an increase in ACR in every case and a huge variability in post-exercise ACR was found. What difference between runners is responsible for such significant variability?

It is not due to the intensity of the exercise; the distance was the same and all runners were amateurs. Nor is it because of some known co-morbidities, as the study population was healthy.

The answer must be in the kidney itself. Our hypothesis is that at one moment during exercise, the proximal tubule stops reabsorbing albumin. Such a condition probably lasts a very short time. It is well known that PEP disappears a few hours after exercise (Poortmans, 1984).

The possible explanation why runners differ so greatly is that some had mild tubulointerstitial damage and a lower capacity to reabsorb albumin. The positive correlation between uNGAL and ACR corresponds with this theory. Another explanation is that in some runners the proximal tubule stops reabsorbing albumin earlier, because it has to reabsorb water and electrolytes more intensively in runners who are dehydrated or exhausted. Those runners with albuminuria should probably drink more and consume more glucose before exercise.

In medicine, we are looking for screening tests that help us in early diagnosis. In sport, on the other hand, we are interested in simple tests which help us in more efficient training.

PEP seems to be a simple test which uncovers early tubulointerstitial kidney damage.

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ASSESSMENT OF ANAEROBIC ENDURANCE BASED ON SELECTED BIOCHEMICAL PARAMETERS IN 400 M/400 M HURDLES MALE ATHLETES

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Abstract. The ongoing development of the modern society may also be easily noticed in sports. Currently, to be able to compete at the highest level at major sporting events, it is essential to conduct scientific research to estimate the individual potential and skill level of an athlete. The aim of this study was to assess the anaerobic endurance in men competing in the running events of 400 m/400 m hurdles based on the estimation of maximum power, as well as selected biochemical and physiological parameters measured in a cardiac stress test at a supramaximal intensity. Seven athletes participated in the study and were subjected to a modified version of the Wingate test (Bar-Or, Dotan, Inbar, 1997; Bar-Or, Inbar, Skinder, 1996) which involved performing three runs of a 12-second endurance test on a cycloergometer at short intervals. This modification of the test allowed a more precise observation and a better understanding of the physiological and biochemical changes that decrease the efficiency as a result of repeated physical effort, which may significantly affect the assessment of the preparation of an athlete, and thus the assessment of the training process.
The most significant changes in the course of the conducted study were observed in the values of the following biochemical parameters: glucose levels, acid–base balance of the blood and lactate levels.

Key words: exercise physiology, anaerobic endurance, athletics

Introduction

Athletics is one of the oldest and the most diverse sport disciplines. The amount and intensity of the exerted work is determined by event type. The 400 m and 400 m hurdles races employ speed, endurance and strength in equal amounts, and the 400 m hurdles races also require proper technique. An equal and simultaneous combination of all the aforementioned elements during 45–50 seconds is usually very difficult due to the quickly increasing fatigue, therefore the final result mostly depends on the athlete's speed endurance characterized by anaerobic metabolic processes occurring in the body (Iskra, 2001).

Physical endurance is the ability to exert hard or long-lasting physical exercise involving large muscle groups. The term also embraces the tolerance to variations in homoeostasis and the ability of quick balance recovery once the physical activity has finished (Górski, 2006; Kozłowski, Nazar, 1995). According to prof. Kubica, physical endurance may be defined as the ability demonstrated by the organism to exert a particular type of physical work, expressed as the maximum level of physical capabilities and rapid restitution processes (Kubica, 1995). Among the factors determining physical endurance, there are: aerobic energetic potential (aerobic endurance), anaerobic energetic potential (anaerobic endurance), anthropological and biomechanical characteristics (age, sex, body height, body weight), motoric abilities (strength, speed, resistance), motivation and physical endurance test conditions (Malarecki, 1981; Zając, Wilk, Poprzęcki, Bacik, 2009). As is mentioned above, in the 400 m and 400 m hurdles races, the key factor determining the result is the efficiency of anaerobic metabolic processes occurring in the body, in which adenosine triphosphate (ATP) is produced via two energy processing systems, anaerobic/lactate-independent and anaerobic/lactate-dependent, supported by a third mechanism: aerobic/lactate-dependent (Boobis, Cheetham, 1986; Greenhaff, Hultman, Harris, 1993). During a 400 m/400 m hurdles race, the first metabolic processes employed by the human body are those endowed with the highest power index, yielding the fastest results. These processes use ATP accumulated in the muscles and phosphocreatine. During the hydrolysis of ATP accumulated in the muscles, the last phosphate residue is detached which yields adenosine diphosphate, inorganic phosphate and energy. ATPase is the enzyme that catalyses this reaction. PCr decomposition is mediated by creatine kinase (CK) and its final products are creatine, inorganic phosphate and the liberated energy. The estimates of the quantity of both energetic compounds in the human body are 2–4 $mmol \cdot kg^{-1}$ for muscle ATP and 20 $mmol \cdot kg^{-1}$ for phosphocreatine in hydrated muscle tissue. The amount of the substrates is sufficient to effectively exert work for as little as the first few seconds of exercise. Importantly, during the use of those energetic substrates, blood levels of lactic acid increase only insignificantly and do not exceed the value of 3 $mmol \cdot kg^{-1} \cdot s^{-1}$ (Heck, Schulz, Bartmus, 2003). To maintain an appropriate level of intensity once the anaerobic/lactate-independent processes have become ineffective, the body starts to produce energy using the anaerobic/lactate-dependent processes. The substrates in the ATP resynthesis via anaerobic glycolysis are glycogen or glucose (Jaskólska, Jaskólski, 2006; Wołkow, Jarużnyj, 1986).

Every mole of glucose involved in the reaction yields 2 moles of ATP. If glycogen-derived glucose is the energetic substrate used, 3 moles of ATP are formed. The difference stems from the use of one mole of glucose in the phosphorylation process producing glucose-6-phosphate. With no involvement of oxygen in the reaction, pyruvate, the final product of the reaction, is converted into lactate. Subsequently, it accumulates in the muscle tissue and then diffuses into the blood (Górski, 2006). The highest considered level of blood acidification by lactate is 20 $mmol \cdot L^{-1}$. However, in athletes competing in sprints, particularly in the 400 m/400 m hurdles races, those values might even reach 25 mmol L^{-1} (Heck, Schulz, Bartmus, 2003). The third and last process of energy production involved during the 400 m/400 m hurdles races is aerobic glycolysis. When pyruvate is formed, in the presence of oxygen it undergoes decarboxylation yielding acetyl CoA. The coenzyme subsequently enters the Krebs cycle, in which the necessary energy is formed as 12 ATP molecules per cycle and 36 ATP molecules per one mole of glucose (Traczyk, 2002). Energy production in aerobic glycolysis is the slowest of the three processes employed during the race, yet it is also the longest-lasting one.

Material and methods

The entire scientific procedure was approved by the Bioethics Committee for Scientific Research at the Jerzy Kukuczka Academy of Physical Education in Katowice before the start of the study on 11th March 2012. The group enrolled in the study consisted of 7 athletes (men) competing in the 400 m and/or 400 m hurdles races. During the procedures including the determination of power and anaerobic capacity, as well as the measurements of body height, weight and composition, arterial blood pressure and heart rate, noninvasive measurement methods were used (Monark Ergomedic 874 E cycloergometer, MCE 5.1 software, InBody 220 Body Composition Analyzer, POLAR Sport tester, GOMED JD-1005 blood pressure meter).

To determine the changes in the processes involved in acid–base balance (pH), the proportion of gases and the level of acidification by lactate, and to verify blood glucose levels, two invasive measurement methods were used, based on taking capillary blood samples from a fingertip and its subsequent biochemical analysis (Siemens Bayer RapidLab 248 blood pH and gas analyser; UV.1209 SHIMADZU UV spectrophotometer; Boehringer-Mannheim enzymatic procedure; HemoCue glucose analyser).

In the conducted study, the athletes participated in an anaerobic power assessment test. The test was composed of three 12 seconds long runs with 5 minute breaks between runs. Pedal load of the cycloergometer was adjusted individually for every subject and corresponded to 75 g/1 kg b.w. In every run, the subject exerted maximum power physical exercise interspersed by intervals of passive rest. Every anaerobic test was preceded by a freely selectable, individual warm-up on a cyclometer, lasting 5–6 minutes. Before the first run and after each of them, the subjects underwent precisely defined measurements.

In the conducted studies, in order to analyse the obtained results, the STATISTICA 8.0 software was used. The statistical analyses included: ANOVA, Tukey's post hoc multiple comparison test and Pearson's correlation. The threshold of statistical significance of the results was set at $p < 0.05$.

Results

Group specifications

The studied group was characterized by similar age (21.9 ±2.52 years) and BMI value (22.2 ±1.08), while some differences were noted in the values of body height (181 ± 6.95 cm) and weight (72.6 ±4.66 kg). Moreover, the studied group had a similarly low quantity of adipose tissue (5.9 ±1.57 kg), but demonstrated significant variations in the values of fat-free body mass (66.7 ±5.42 kg), total body water (48.8 ±3.88 kg) and muscle tissue content (38.2 ±3.27 kg).

In the ergometric tests, the subjects performing three runs of a 12-second test were subjected to measurements aimed at assessing the following absolute values: maximum power [W/kg], mean power [W/kg] and mean exerted work [J/kg].

Comparison of ergometric values from 3 runs

The ANOVA method did not reveal any significant influence of repeated supramaximal exercise on maximum power ($F = 2.54$; $p < 0.106$) and mean power ($F = 2.35$; $p < 0.124$) values. However, a strict correlation between the maximum anaerobic power and mean power of exercise in each run was revealed: Ex_1 ($r = 0.893$; $p < 0.007$), Ex_2 ($r = 0.808$; $p < 0.028$) and Ex_3 ($r = 0.881$; $p < 0.009$).

Table 1. Results of ergometric measurements from all three runs

(n = 7)	Mean	Max.	Min.	SD	CV	Kurtosis
Max power [W/kg]						
Ex_1	12.39	13.5	11.6	0.641	5.178	0.325
Ex_2	12.01	12.9	11.5	0.543	4.519	–0.823
Ex_3	11.66	12.5	10.8	0.624	5.354	–0.908
Mean power [W/kg]						
Ex_1	10.53	11.3	10.0	0.492	4.676	–1.236
Ex_2	10.29	11.0	9.8	0.422	4.102	–0.265
Ex_3	9.97	10.9	9.2	0.525	5.265	1.409
Exerted work [J/kg]						
Ex_1	126.43	136.0	120.0	5.884	4.654	–0.852
Ex_2	123.14	131.0	118.0	4.845	3.934	–0.792
Ex_3	119.86	130.0	111.0	5.843	4.875	1.363

Results of biochemical tests

In order to obtain biochemical parameters from the studied group, the athletes were subjected to the measurements of: blood glucose, blood lactate and acid–base balance of the blood (pH). Each parameter was determined before the first anaerobic test, in order to obtain the baseline values (BL), and then in the 4th minute of restitution after each concluded run, in order to obtain the post-exercise values (Ex_1, Ex_2, Ex_3).

The lowest mean value of blood glucose levels obtained in the studied group was the baseline value 91 ±6.73 [mg/dl]. Physical exercise caused an increase in the mean blood glucose levels. Blood glucose levels were 97.85 ±9.34 [mg/dl] after the first run, 100.71 ±10.05 [mg/dl] after the second run, and 105.43 ±10.20 [mg/dl] after the third run of the test (Figure 1).

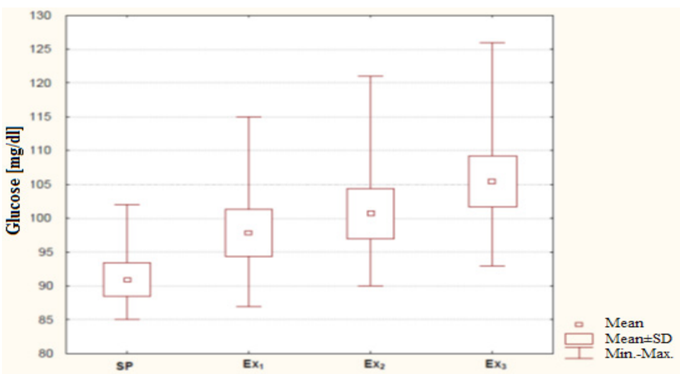

Figure 1. Graphical representation of the obtained blood glucose values

The analysis of variance indicated a significant effect of repeated supramaximal exercise on the increase in blood glucose levels ($F = 3.02$; $p < 0.05$). Statistical significance of the increase in blood glucose levels compared to the baseline value was revealed only for Ex_3, with $p < 0.034$ (Figure 1).

The analysis of variance indicated a significant effect of repeated supramaximal exercise on the increase in blood lactate levels ($F = 231.87$; $p < 0.001$). Moreover, significant differences were found in the following result pairs: BL vs. Ex_1, BL vs. Ex_2, and BL vs. Ex_3, with $p < 0.001$, as well as in the following pairs: Ex_1 vs. Ex_2, Ex_1 vs. Ex_3, and Ex_2 vs. Ex_3, with $p < 0.004$ (Figure 2).

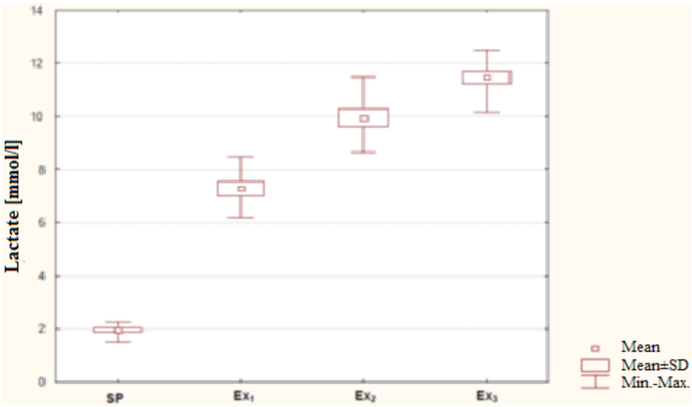

Figure 2. Graphical representation of the obtained blood lactate values

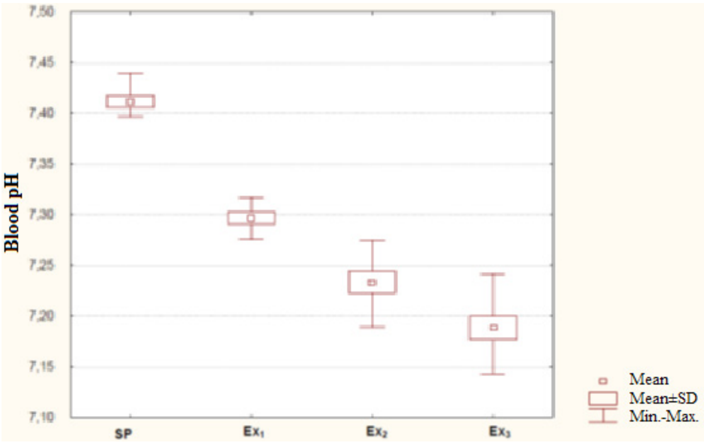

Figure 3. Graphical representation of the obtained blood pH values

The analysis of variance indicated a significant effect of repeated supramaximal exercise on the decrease in blood acid-base balance ($F = 106.11$, $p < 0.001$). Moreover, significant differences were found in the following result pairs: BL vs. Ex_1, BL vs. Ex_2, and BL vs. Ex_3, with $p < 0.001$, as well as in the following pairs: Ex_1 vs. Ex_2, Ex_1 vs. Ex_3, and Ex_2 vs. Ex_3, with $p < 0.02$ (Figure 3).

The course of post-exercise restitution

In the conducted study, arterial blood pressure and heart rate were subjected to a thorough analysis. Both parameters were measured at baseline and in the restitution period, after each of the test runs performed. As for arterial blood pressure, the mean baseline values were 124 ±7.48 [mm Hg] for SBP and 83 ±7.08 [mm Hg] for DBP. As the subsequent endurance tests were conducted, the obtained values were slightly different. Compared to the baseline values, an increase was observed in systolic blood pressure, while a decrease was observed in diastolic blood pressure, reaching the mean values of 131 ±9.76 [mm Hg] and 76 ±8.62 [mm Hg], respectively, at the end of the experiment (Figure 4).

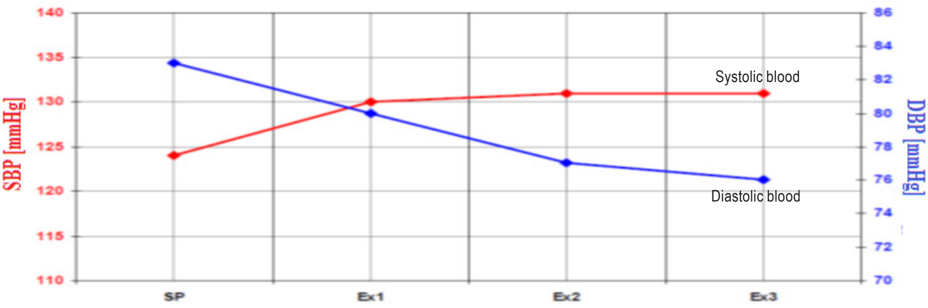

Figure 4. Graphical representation of blood pressure values obtained at baseline (BL) and after each test run (Ex_1, Ex_2, Ex_3)

As for heart rate, the mean baseline value was 66 ±9.46 [BPM]. The highest heart rate values in the studied group were obtained immediately after each of the anaerobic test runs (Ex_1: 151 ±9 [BPM], Ex_2: 162 ±7 [BPM], Ex_3: 161 ±10 [BPM]), and decreased significantly afterwards. The lowest HR values were noted between the 3rd and the 4th minute of restitution after the first (110 ±19 [BPM]) and the second (124 ±22 [BPM]) test run. After that period, heart rate increased until another endurance test run. In the case of restitution after the third run, the heart rate values continued to decrease until minute 5 (110 ±19 [BPM]). Detailed graphical representation of the course of all three restitution periods is presented in Figure 5.

The analysis of variance of the course of all restitution values indicated a significant difference only between the second and the third restitution period in the 5th minute of measurement ($F = 5.50$; $p < 0.02$).

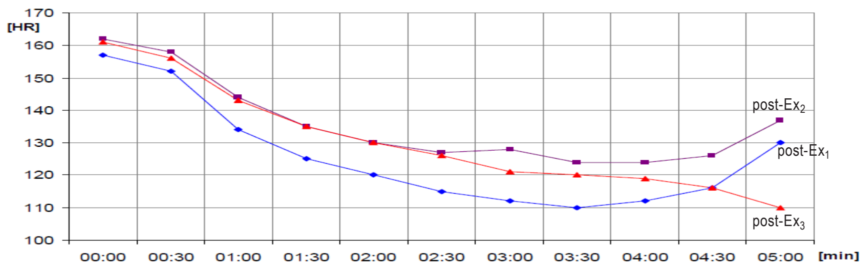

Figure 5. Graphical representation of the mean course of blood pressure changes after each endurance test run

Discussion

Endurance tests conducted among athletes competing in different disciplines

of sport are growing in popularity as a tool to control training level and plan training load. Increased energetic potential of skeletal muscles is one of the main effects of training in speed/endurance sports. In the first phase of a run, phosphagenic processes and anaerobic glycolysis are used, enabling the athlete to exert and continue the exercise at the intensity close or equal to maximum power. In the second phase, aerobic glycolysis dominates and its use enables the athlete to continue the exercise despite a significant decrease in power.

Effect of speed training on speed endurance

In the group of athletes competing in the 400 m/400 m hurdles races, high values of maximum power were detected. The obtained values were similar to those presented in previous studies conducted in athletes competing in sprints: 100, 200 and 400 m races (Gabryś, 2000; Gabryś, Szmatlan-Gabryś, 1997; Kosendiak, Habiniak, Markowski, 1999). The well documented effect of intense speed training on adaptive changes in the muscular system results in increases in muscle mass via hypertrophy, which occurs mostly in the fast twitch muscle fibre types A and X. The phenomenon involves increases in muscle diameter and the content of contractile and cytoplasmic proteins in the muscle (Zając, Wilk, Poprzęcki, Bacik, 2009). The adaptive processes also include a more efficient use of energy substrates supplied with diet and their effective metabolism, as well as a more pronounced activation of anaerobic processes and an increase in buffer capacity of the blood (Górski, 2006). In this study, the significant effect of training in athletes competing in the 400 m/400 m hurdles races on the values of the muscle and adipose tissue content, but also on the maximum power, mean power and exerted work parameters, was confirmed. This may indicate a good preparation for the applied exercise load in subjects, which in turn allows obtaining better results in sprints. The above changes directly contribute to an increase in the maximum power index in the first few seconds of physical exercise, a longer-lasting peak value of the index and a milder decrease at the end of the cardiac stress test performed.

Effect of repeated speed exercise on the parameters describing anaerobic endurance

In athletes participating in the three repeated, 12-second cardiac stress tests at a supramaximal intensity, changes in the obtained maximum power values were observed. A tendency of the maximum power value to decrease compared to the previous results obtained in cardiac stress tests was observed in the studied athletes. In the studies conducted by Watt et al. (Watt, Hopkins, Snow, 2002) involving the assessment of the results of repeated cycloergometric tests, obtained in a double 30-second Wingate test with a 4-minute interval between the runs, a significant decrease in the values of maximum and mean power was observed. In this study, applying shorter exercise and longer intervals might have contributed to the lack of significant changes in the obtained parameters of maximum and mean power. During a cardiac stress test, loss of energy resources occurs in the phosphagenic and anaerobic/aerobic glycolytic processes.

The loss of energy substrates in the aforementioned processes leads to a rapid activation of reactions aimed at the recovery of the resources (Weber, 2002). The ability of a quick regeneration might be the cause of maintaining high maximum and mean power indices in the repeated anaerobic endurance test. In a cardiac stress test lasting 30 seconds or longer, it is impossible for the body to fully rebuild the depleted energy resources during an interval between the runs that lasts a few minutes, due to the large amount of resources that are lost. Studies confirming this observation are, e.g., those conducted by (Parra, Cadefau, Rodas, Amigo, Cusso, 2000) in which, by using muscle biopsy, a significant post-exercise decrease in the concentrations of phosphocreatine (PCr) and an increase in the levels of creatine (Cr) were observed in the muscle after a 30-second Wingate test. In this study, the progressive decrease in the values of maximum and mean power in 5 athletes, with a concurrent lack of such correlation in 2 subjects, resulted in a decrease exclusively in the aforementioned parameters in the studied group. In order to elucidate the differences in the values of the power generated during repeated speed exercise, an assessment of acid–base balance and glucose accessibility for the resynthesis of energy resources was performed.

Effect of biochemical processes on the ability of anaerobic exercise

The repeated exercise at a supramaximal intensity performed during the study significantly contributed to the disturbance of homoeostasis in each athlete from the beginning of the first test run. The post-exercise values of all three measured parameters: glucose levels, acid-base balance of the blood and lactate levels, demonstrated significant differences compared to the baseline values. The biochemical measurements conducted during the cardiac stress tests revealed strict correlations between selected parameters and the results of the ergometric tests obtained by the athletes.

Changes in blood glucose levels and the ability of anaerobic exercise

In the first phase of speed exercise, the body uses energy obtained in the anaerobic/lactate-independent processes, in which no significant differences in blood glucose levels are observed. However, the activity of the autonomic nervous system is increased, which affects the physiology of the sympathetic nervous system during intense physical activity, leading to the activation of adrenalin, noradrenalin and glucagon production and the subsequent increase in their concentrations. These three hormones increase glycogenolysis activation in the liver and muscles in which glucose is stored in the form of glycogen (Czajkowska-Pączek, Przybylski, 2006). Thanks to the presence of the aforementioned hormones and the process of glycogenolysis, glycogen is converted into glucose whose increased blood levels are detectable after only 10–20 seconds from the start of speed exercise (Gabryś, 2000). Such changes were confirmed in the conducted study, and what is more, an increase in blood glucose levels was found after each test run. Moreover, the observed uniform increase in blood glucose levels may suggest a high efficiency of the glycolytic processes in the athletes, which may have a direct influence on passing the race distance more effectively.

Changes in blood lactate levels and the ability of anaerobic exercise

Anaerobic glycolysis used to balance the energetic demands of the muscles leads to the release of considerable amounts of lactate. The compound is produced in the process due to the accumulation of pyruvate, which, in the absence of oxygen and in the presence of lactate dehydrogenase, is converted into lactate. High intensity exercise along with a large number of fast twitch muscle fibres involved result in a significant increase in lactate blood levels (Kin-Isler, 2006; Özturk, Özer, Gokce, 1998). Indeed, in the conducted experiment, a significant increase in lactate blood levels was observed. The course of the process was identical in the post-exercise period in all subjects, either after the first or every further test run. Increased blood lactate levels exert specific effects in the muscles, whose symptom is an increasing fatigue of the athlete marked by a tendency of the maximum and mean power values to decline in the study. Moreover, this observation is also a proof of high utilization of the glycolytic potential in the athletes, although the obtained lactate levels were not as high as those accompanying supramaximal exercise in sprints. Additionally, it is important to determine the parameter of acid–base balance in order to precisely monitor muscle homoeostasis in the conducted study.

Changes in acid–base balance and the ability of anaerobic exercise

Lactate levels are the main parameter affecting the acid–base balance in the setting of anaerobic exercise. Increased lactate levels cause a proportional decrease in bicarbonate levels and the activation of buffer reactions in the body, aimed at reducing the growing systemic acidification (Hennessey, 2008; Konturek, Brzozowski, 2003). In people with a high level of training in speed disciplines, no changes in the resting values of blood acid-base balance occur, which was also confirmed by the results of this study. The lack of a significant decrease in maximum and mean power might therefore be caused by the increased tolerance to systemic acidification via an increased buffer capacity of the muscles and a quicker recovery from the occurring deviation from the reference values. The more buffering bases are used, the better the capacity of acidification neutralization via hydrogen ion binding in the muscles is. Undoubtedly, it is affected by an increased capillary growth in the muscles, caused by muscle hypertrophy occurring as an adaptive reaction to specific training loads.

Conclusions

1. Training conducted by athletes competing in the 400 m/400 m hurdles races allows them to obtain high values of maximum anaerobic power.
2. Performing repeated supramaximal exercise by the subjects did not significantly affect the values of maximum and mean power.
3. A strict correlation was observed between the obtained values of maximum and mean power during repeated supramaximal exercise.
4. Repeated supramaximal exercise induces a decrease in the value of blood acid–base balance, as well as blood lactate and glucose levels.
5. Performing repeated supramaximal exercise by the subjects leads to an increase in systolic blood pressure and a decrease in diastolic blood pressure.

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