University of Szczecin
Faculty of Physical Culture
and Health Promotion

3/2018

Central European Journal of Sport Sciences and Medicine

EDITORIAL OFFICE
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University of Szczecin, Poland

TEXT DESIGN AND TECHNICAL EDITORIAL | Wiesława Mazurkiewicz

COVER DESIGN | Agnieszka Nawrocka

Print edition is the original published version of the journal
Indexed in: AGRO, Index Copernicus, Google Scholar, PSJD, SafetyLit, Pol-Index

The names of the reviewers are available on the journal's website: www.wnus.edu.pl/cejssm

ISSN 2300-9705

PUBLISHER | Wydawnictwo Naukowe Uniwersytetu Szczecińskiego
Printed in 57 copies

Central European Journal of Sport Sciences and Medicine

a quarterly journal

University of Szczecin
Faculty of Physical Culture
and Health Promotion

Vol. 23, No. 3/2018

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GOLF PUTTING: EQUIVALENT PERFORMANCE WITH BALL FOCUSED AND TARGET FOCUSED AIMING

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Abstract This study addressed several inconsistencies and omissions in golf putting research by testing the performance impact of target focused aiming. Participants were 22 high-level and experienced golfers, currently using ball focused aiming. Participants were allocated in a quasi-random fashion to ball or target focused aiming conditions and each performed 32 putts under competitive conditions on a natural putting green from a distance of 8 ft. Data were recorded as putts holed or missed and further categorised into putts missed long, short, left, right, short left, short right, long left and long right. There was no significant difference *between* conditions ($p > 0.05$) for any of the categories tested, despite participants' prior extreme familiarity and expressed preference for the ball focused technique. These results notwithstanding, we discuss possible explanations for target focused benefits, including the role of vision during putting, the impact of intention during execution and possible expectancy effects. While these findings hold potential implications for golf coaching, more research is clearly required to further understand causative mechanisms and to clarify the existence and nature of advantage for one technique over the other. Based on this study, we recommend that high-level and experienced golfers might try target focused aiming as a 'cost-free' experiment.

Key words high-level golfers, visual aiming, intention, coaching

Introduction

Technical skill creativity and innovation is an inevitable aspect of sport (Bar-Eli et al., 2006; Carson, Collins, 2011), most typically introduced by a few athletes and then, sometimes, adopted by many. Positive examples of innovation include Dick Fosbury's influence on the high jump and Jan Boklov's ski jumping technique. Both performers were first considered to have had unconventional styles. Recently, golf has experienced a similar challenge to known, accepted and comfortable orthodoxy regarding the closed and self-paced skill of putting. Specifically, while golfers have long kept their eyes fixed on the ball during the putting stroke, 'ball focused aiming' (hereafter termed BFA), several professionals (e.g., Major champions Jordan Speith and Louis Oosthuizen) have

sometimes opted to direct their head, neck and eyes towards the target, 'target focused aiming' (hereafter termed TFA; Figure 1). For clarity, we define TFA as golfers fixing their gaze on the target (i.e., entry point of the hole for straight putts or the breaking point for sloped putts) prior to stroke initiation and throughout the execution. Notably, however, past golf research examining the position of the eyes have *only* considered BFA (e.g., Vickers, 1992; Vine, Moore, Wilson, 2011), meaning that eye gaze studies of TFA are under-researched and a topic of both practical and theoretical interest (Moffat, Collins, Carson, 2017).

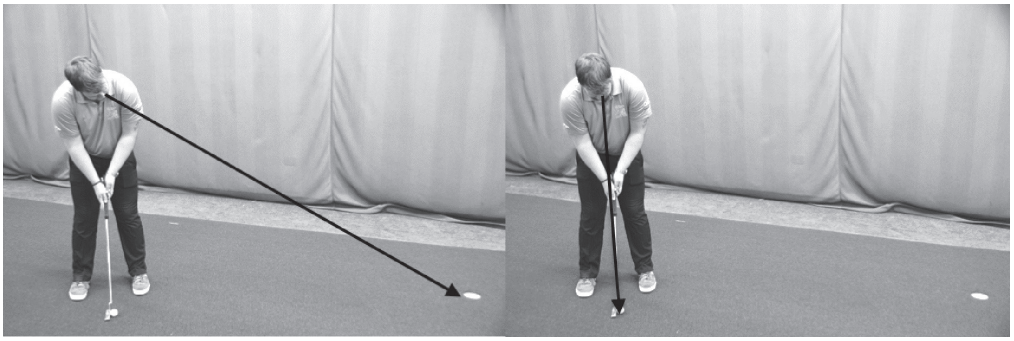

Figure 1. Golfer using TFA (left) and BFA (right) method

Regarding the underlying processes responsible for the performance and motor learning effects of TFA, several existing theories warrant consideration (e.g., Fischman, Christina, Vercruyssen, 1981; Shea, Morgan, 1979). However, for our present, mainly practical, purpose within a series of investigations currently underway, we will address this problem through Christina's (1987) basic and applied research framework. Christina distinguishes motor learning research across three levels (or motivations) of relevance for practical problem solving: Level 1, to "develop theory-based knowledge appropriate for understanding motor learning in general with no requirement to demonstrate its relevance for solving practical problems"; Level 2, to "develop theory-based knowledge appropriate for understanding the learning of practical skills in practical settings with no requirement to find immediate solutions to practical learning problems", and Level 3, to "find immediate solutions to practical learning problems in practical settings with no requirement to develop theory-based knowledge at either Level 1 or Level 2" (p. 29). In other words, Level 1 research would typically explore general motor learning principles *through* sport, Level 2 research would seek to understand practices *of* sport and Level 3 research is designed to have a direct influence *for* sport (Collins, Kamin, 2012). Importantly, however, Christina explains that the interaction between Levels 1–3 *should be* such that basic theory not only informs practice, but practice must also inform theory. Accordingly, the empirical element of this paper is focused on Level 3, in that this research examines the impact of TFA as a practical tool for reaching higher golf performance.

Currently, the evidence is equivocal as to whether TFA confers any performance advantage over BFA, especially for high-level golfers with an already well-established BFA style (Carson, Collins, 2016a). Importantly for coaching purposes, greater knowledge of whether it *is* advantageous, for whom, when and why, is necessary for its optimal application and before there can be a move towards an expertise-based approach to decision making

(Collins, Burke, Martindale, Cruickshank, 2015). While it is beyond the scope of the present study to answer all these questions definitively, it aims to make some progress towards addressing this crucial need.

Providing the impetus for this recognised need, Moffat et al. (2017) recently conducted a review of TFA studies, over a period of 50 years (e.g., Bowen, 1968; MacKenzie, Foley, Adamczyk, 2011). In summary, their review found that it was currently impossible to evaluate TFA effectiveness due to several important inconsistencies and omissions across studies (see Moffat et al., 2017 Table 1 for a detailed account of study characteristics, pp. 37–41). For example, not all studies were conducted in representative golf environments or with golfers' own preferred equipment (e.g., putter). Furthermore, there was insufficient consideration of the meaningfulness of the task or relative engagement of participants as compared to a putting task under competitive conditions (cf. Christensen, Sutton, McIlwain, 2016). Consider, for instance, the difference in motivations between an undergraduate student participating for module credits versus a genuine beginner golfer looking to improve their long-term skills and sport participation. More positively however, recent studies have been increasingly thorough in approach. For example, MacKenzie and MacInnis (2017) evaluated a far (TFA) versus near (BFA) target visual focus strategy with 6 ft., 10 ft. and 14 ft. breaking putts, among 28 experienced but high handicap golfers ($M_{handicap}$ = 12.5). Results showed a significantly higher percentage of successful putts with TFA in comparison to BFA, especially for left-to-right breaking putts. Results indicated that TFA achieved a small but significantly higher percentage of successful putts (40%) compared to BFA (37%). This result was predominantly due to a 5% positive difference at 10 ft. (39% vs. 34%), which could indicate a possible confounding variable of distance when evaluating TFA effectiveness. In an earlier study, MacKenzie et al. (2011), using 32 high handicap golfers ($M_{handicap}$ = 18.7), examined process measures of putter head kinematics at 4 ft. and 13 ft. and determined that practice with TFA resulted in a significant reduction in putter speed variability compared to practice with BFA. However, TFA did not statistically affect the quality of impact, as assessed by variability in face angle, stroke path and impact spot at the precise moment the putter head contacted the ball. Crucially, nor did TFA improve performance at either of these distances when compared to a matched BFA group.

Perhaps unsurprisingly, as a result of inconsistency in past research findings, different researchers have drawn varying conclusions regarding TFA effectiveness. Alpenfels, Christina and Heath (2008), MacKenzie and MacInnis (2017) and MacKenzie et al. (2011) all reported TFA benefits of kind (either process or outcome), whilst Gonzalez, Kegel, Ishikura and Lee (2012) reported a TFA disadvantage. Accordingly, Moffat et al. (2017) suggested that a coherent chain of investigation was required, with methodological features resolutely combined with improved control over variables as our understanding of TFA develops (cf. Goginsky, Collins, 1996). First and foremost, however, this research chain must begin with establishing whether TFA *does,* in fact, make a putting performance difference, when compared to BFA. Accordingly, this study addressed several past inconsistencies and omissions by testing TFA with BFA among high-level golfers in a naturalistic putting environment (on an actual golf green) while golfers used their own preferred putters and engaged in a meaningful putting competition. Specifically, we were interested in whether novel use of TFA among established BFA golfers would reveal any short-term difference in performance effectiveness.

Given the vast volume of practice completed by these participants on BFA, it was reasonable to assume that employing TFA for the first time would be associated with a performance decrement associated with the removal of vision on the ball. As previous literature suggests, visual information of the ball and putter enables the golfer to maintain precise alignment of the putter face at impact, which is necessary for successful performance (Nicklaus,

Bowen, 2009; Pelz, Frank, 2000; Wannebo, Reeve, 1984). However, considering the inconsistency of results and methodological issues within the TFA literature mentioned already, we were interested to see if any advantage and/or decrement did occur.

Method

Participants

Twenty-three high-level golfers of both professional (2 male, right-handed, M_{age} = 34 years, SD = 7) and amateur (18 male, 15 right-handed and 1 left-handed, M_{age} = 19.4 years, SD = 0.9, $M_{handicap}$ = 3.5, SD = 2.3 and 3 female, right-handed, M_{age} = 19 years, SD = 1.6, $M_{handicap}$ = 5.3, SD = 4.1) status were recruited for this study. Amateur golfers were high-level, as reflected by their low handicap averages. However, one participant was removed (adjustment n = 22) from the trials on his self-admission of having no interest in competing and committing to the task. Inclusion criteria required golfers to (a) be a current registered member of the Professional Golfers' Association of Great Britain and Ireland or be an amateur golfer with a current single figure handicap, (b) be available for four 20 min testing sessions, distributed before and after two competitive rounds of golf over a consecutive 2 day period, (c) have normal or corrected vision and (d) have no previous experience using TFA as determined by self-report. We obtained ethical approval from the university's ethics committee prior to conducting the study and all participants provided written informed consent prior to their participation.

Procedure

Two holes on the Victoria Golf Club practice putting green (Vilamoura; European Tour venue for the Portuguese Masters Championship) – identified for their challenging breaks and slopes – were selected as the venue for these putting trials. Green speed for both days was typical of championship conditions, registering 10 on the Stimpmeter for each day.[1] Eight golf tee pegs were positioned around each hole, 8 ft. from the centre and equidistant to each other (Figure 2) providing a variety of challenging putts for participants (e.g., breaking right-to-left, uphill breaking, downhill breaking, straight putts and breaking left-to-right putts) and pushed just below the surface of the grass. These determined the points from which participants should putt and place his/her ball during the pre-putt routine.

Participants were assigned in a quasi-random fashion either to a BFA (n = 11) or TFA group (n = 11), with the groups balanced on professional/amateur status, handicap, handedness and gender. In an attempt to generate a meaningful putting competition, each participant was informed that prize money of €100 would be awarded to the golfer with the highest number of putts holed in each group, and we provided a competitive leaderboard that was promulgated to all participants over the 2 days of trials (Baumeister, 1984; Beilock, Carr, 2001; Guadagnoli, Bertram, 2014). Participants were instructed to follow their normal pre-putt routine and, in their own time, to attempt to hole as many putts as possible. Participants used their own putters and all putts were performed with new unmarked and legally conforming golf balls that we provided (Titleist Pro V1). The TFA group were provided with the instruction to follow their normal pre-putt routine and in their own time attempt to hole as many putts as possible whilst fixing their gaze on the target (e.g., entry point of the hole for straight putts or the breaking point for sloped putts) for

[1] Stimp is the measure of green speed and is determined by rolling a ball with an initial speed of 6 ft. s^{-1} from an elevated grooved track and measuring how far it rolls on a flat portion of the putting surface.

a minimum period of 2 s prior to stroke initiation and to leave the eyes fixed on this position throughout the putting stroke (cf. Binsch, Oudejans, Bakker, Savelsbergh, 2009; Vickers, 2016). In contrast, the BFA group members were instructed to putt as they would naturally. To ensure compliance, observers made manipulation checks during each trial and through participant debriefs following each trial block to ensure that BFA and TFA instructional sets were followed.

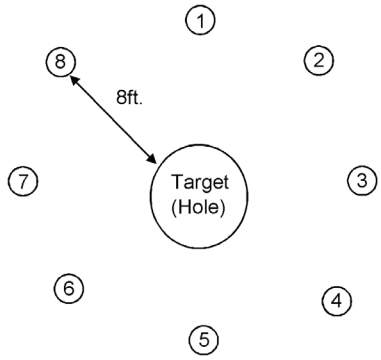

Figure 2. A schematic representation of the putting layout

The experiment was subdivided into four blocks of eight putts, resulting in a total of 32 putts over a 2 day period. Both groups completed their eight putts on two different holes for each day, progressing in either a clockwise or anticlockwise direction during the pre-round block, then in the alternate direction during the post-round block (see Figure 2). Importantly, pre-post round blocks, hole and direction were balanced between the two conditions. The putting distance (8 ft.) and location of each putt (eight different locations) were carefully selected (Karlsen, Smith, Nilsson, 2008). According to Pelz (1999), during competitive play 8 ft. represents a meaningful distance for a typical birdie putt, which is converted successfully approximately 50% of the time by tournament professional golfers (PGATour, 2017). Prior to commencement of the experimental putting trials, each participant was informed of the trial protocol, including the holes to be used and each of the eight marked locations around each hole. Participants were then provided with a 5 min familiarisation period in which they could putt from anywhere other than the selected trial holes using the BFA method only. The instruction for the TFA group to use BFA during the familiarisation period ensured the integrity of the novelty effect and negated any chance of raising performance during the trial. This process permitted participants to become accustomed to the characteristics of the green, such as speed, slopes, undulations and grain direction, which is a typical practice regimen for golfers prior to a competitive round. Inclusive of the familiarisation warm-up, the duration of each of the four blocks of trials ranged between 15–20 minutes per participant (Figure 3).

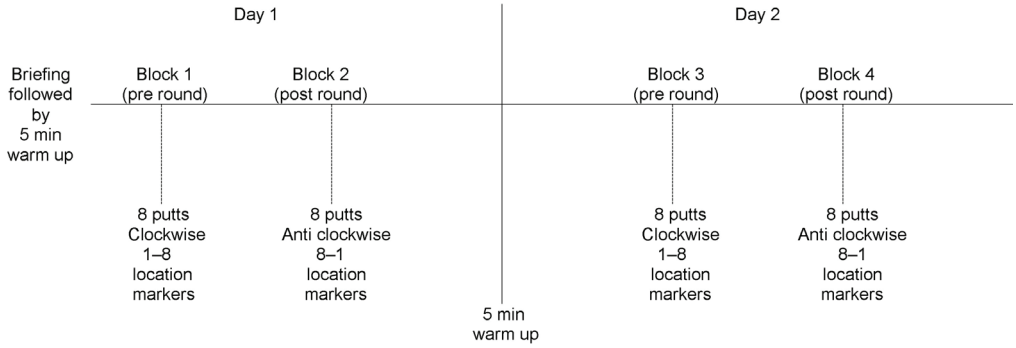

Figure 3. Experimental design

Following each putt, data were gathered using a customised score sheet. Results were first recorded as having been holed or missed, with missed putts further categorised based on a quadrant through the hole, creating four independent distance combined with direction outcomes.

Data Analysis

Data were analysed using SPSS Statistics 23.0 (IBM Corporation, New York, USA) software. We conducted independent samples *t*-tests on the following measures: the number of putts holed and for missed putts we assessed for misses short, long, right, left, short right, short left, long right and long left. The variable "short" was defined by the sum of scores for missed putts short left and short right. The variable "long" was defined by the sum of scores for putts missed long left and putts missed long right. The variable "left" was defined by the sum of scores for putts missed short left and putts missed long left. The variable "right" was defined by the sum of scores for putts missed short right and putts missed long right. Effect sizes were assessed using the Cohen's (*d*) statistic and a *p*-value of less than 0.05 was considered as statistically significant.

Results

Descriptive statistics (means and standard deviations) for all measures are shown in Table 1. A consistent finding across all tests was that of a nonsignificant difference between TFA and BFA conditions. For outcome measures, results showed no significant difference between the mean putts holed, $t(20) = -0.33$, $p = 0.74$, $d = -0.14$. There were also no significant differences when comparing putts missed short left, $t(20) = 0.85$, $p = 0.41$, $d = 0.37$, long left, $t(20) = -0.26$, $p = 0.80$, $d = -0.11$, short right, $t(20) = 0.50$, $p = 0.63$, $d = 0.21$, long right, $t(20) = -0.07$, $p = 0.95$, $d = -0.03$, left, $t(20) = 0.00$, $p = 1.00$, $d = 0.00$, right, $t(20) = 0.22$, $p = 0.83$, $d = 0.09$, long, $t(20) = -0.42$, $p = 0.68$, $d = -0.18$ and short $t(20) = 0.75$, $p = 0.46$, $d = 0.32$. Accordingly, these data determined that putts holed or putts missed were neither improved nor diminished by the imposition of the novel TFA approach among high-level golfers who preferred and were well established with the BFA approach.

Table 1. Group comparisons of putting performance

Condition	Putts Holed	Short Left	Long Left	Short Right	Long Right	Miss Left	Miss Right	Miss Long	Miss Short
TFA	11.27 ±2.41	0.82 ±1.17	7.82 ±3.40	2.00 ±2.83	10.09 ±3.02	8.64 ±3.14	12.09 ±3.96	17.91 ±3.05	2.82 ±3.16
BFA	11.64 ±2.73	0.45 ±0.82	8.18 ±3.19	1.55 ±1.13	10.18 ±3.12	8.64 ±3.26	11.73 ±3.69	18.36 ±1.86	2.00 ±1.79

Discussion

The purpose of this study was to address several inconsistencies and omissions within existing golf putting literature when testing the use of TFA compared to BFA with high-level golfers. In summary, and consistent with some previous findings pertaining to TFA performance effectiveness (e.g., Cockerill, 1978; MacKenzie et al., 2011), no significant difference between these putting techniques was found. In fact, to detect a significant difference ($p < 0.05$) for the number of putts holed, a *post hoc* analysis using Cohen's (1992) power primer calculation revealed the necessity for a sample size of 51,826. While there is a substantial literature advising against the use of post hoc power analyses (e.g., Levine, Ensom, 2001), the simple point here is to demonstrate the low magnitude of impact which this more naturalistic manipulation exerted.

In view of this main finding, there are several interesting considerations that could be drawn. Firstly, it is possible that TFA does not necessarily benefit high-level golfers but helps to buffer against negative performances. One way in which this might be operationalised is to prevent distraction from putter head mechanics during the stroke. Another consideration is the extent to which TFA represented a sufficiently novel task when compared to already well established BFA control processes. In other words, the interaction between important putting processes involved in BFA and TFA were not different enough to cause any performance decrement. Finally, it may be that the visual change from BFA to TFA represents no challenge for high-level golfers. This would be surprising since some claim advantages from changing to TFA: nevertheless, this possibility must be considered. Whichever explanation is subsequently supported by further investigations, these nonsignificant research findings may be of considerable interest to golf practitioners and researchers.

So why might some find TFA advantageous?

It must be reiterated that, based on these data, no clear advantage or disadvantage for putting performance has emerged. However, as explained earlier, there are certainly some performers who endorse TFA as advantageous; a suggestion, which clearly merits ongoing investigation. Accordingly, in agreement with Christina's (1987) recommendation for promoting practice-informed theory, we now provide several theoretical reasons that *could* underpin the findings in high-level and experienced athletes. In turn, these explanations should serve to usefully inform future research to investigate TFA; thus, representing a reciprocal relationship between the different research levels.

Firstly, vision, or what golfers attend to, similar to advice to "keep your head still whilst putting" (see Lee, Ishikura, Kegel, Gonzalez, Passmore, 2008) may not be so important to performance once the green has been read and the stance adopted. Putting is notably different from other dynamic interceptive tasks where vision has been demonstrated to be an important factor (e.g., clay pigeon shooting; Causer, Bennett, Holmes, Jannelle, Williams,

2010), because neither the ball nor target are in motion during the execution phase of this motor activity, making no ongoing visual activity (e.g., target tracking) needed. Compared to dynamic ball striking, the putting task is simpler (cf. Christensen et al., 2016) and more akin to target-oriented sports such as pistol shooting or archery. In this regard, there is evidence that closed and self-paced action skills progress from initially vision-dominant control to largely kinaesthetic-dominant control with learning, as shown by Bennett and Davids (1995) who found that skilled power lifters showed no performance decrement across execution conditions of full, ambient and no vision, whereas lesser skilled power lifters were hindered by these vision manipulations.

Secondly, and following from the previous point, the lack of effect from BFA and TFA technique manipulations may derive from the greater importance of some nonvisual factors to performance. Among possible nonvisual factors, is the role of psychomotor *intention*; referring to the activation of an internal motor skill representation through mental control (Schack, 2003). As an internal factor, intention reduces attention allocated toward external factors, such as visual stimuli (Jeannerod, 1994; Loze, Collins, Shaw, 1999; Shaw, 1996). Indeed, data derived from pre-shot EEG alpha power reactivity during elite air pistol shooting (Loze, Collins, Holmes, 2001; Loze et al., 1999), suggests that shots of greatest success occurred when *not* focussing on where the pistol was aimed; as indicated by reduced visual cortex activity. A similar focus on nonvisual activity may apply to putting with the TFA method. As Loze et al. (2001) explain, increased alpha power was associated with a state of internal focus as the elite shooter switched focus to the trigger pull following aiming completion (Wertheim, 1981). In other words, even though the eyes might be directed toward, even fixated on, an external target, visual processing was, in fact, decreased because shooters redirected their focus onto the execution process.

Thirdly, an explanation for these nonsignificant results that emanated from the debriefing sessions with golfers in the TFA group, is that golfers found the new TFA experience liberating in its tendency to redirect attention away from an over-focus on the ball to a new focus on the intended target. In effect, TFA may have screened against an over-focus on less important task-related cognitions by removing an over-focus on disruptive, external visual cues (Collins, Carson, Toner, 2016; Vickers, Williams, 2007) that may even lead to misdirected attention toward perceived inaccuracies in club head movement. In other words, TFA *might* be advantageous to high-level golfers not because it offers any additional benefits to performance per se, but because it limits the impact of detrimental factors. In the case of data presented in this study, the potential decrement in performance may have been countered by the removal of another challenge to putting under BFA conditions.

Finally, considering extensive work on expectancy effects within the psychology literature (e.g., Rosenthal & Rubin, 1978), coaching practitioners and researchers must be cognisant of the potential for an interpersonal expectancy effect that may have enhanced TFA putting performance. While all these explanations seem reasonable, we favour the idea that improved internal *intention* may best explain why a novel putting approach did not contribute to a decrement in golfers' putting performance in this study. The importance of this internal mental representation derives from data and methodologies of Bertollo et al. (2016) and Loze et al. (2001) and from related closed skill research at the elite level. The simple principle underpinning these findings is that focusing on important, task-relevant technical skill elements can positively influence athletic performance (Carson, Collins, 2016a). This theorised explanation for some possible advantages to TFA (or at least from a demonstration of its neutrality with respect to performance decrements) should be further investigated in studies that manipulate nonvisual factors in putting performance, perhaps through studies of neural activations with varied attentional control strategies across the skill's entirety (Christensen et al., 2016; Eysenck, Derakshan, Santos, Calvo, 2007).

While this study's strengths include the fact that the putting task was completed under more ecologically valid conditions, there were also important limitations. For example, evaluation of participant anxiety, through either psychometric or psychophysiological measures, to ensure equal levels of anxiety across TFA and BFA groups was not included (e.g., Chamberlain, Hale, 2007; Smith, Smoll, Cumming, Grossbard, 2006). Similarly, qualitative data on golfers' perceptions were not obtained (cf. MacPherson, Collins, Morriss, 2008). Also, this study only examined putting from 8 ft. and did not address any interactive effects at different putting distances when using TFA versus BFA. Of importance, a possible weakness in this study that warrants further consideration in future research, is that we studied only high-level golfers with prior BFA experience and do not know how prior experience with TFA might have affected these results. Our a priori expectation that golfers preferring, and familiar with only, BFA might have experienced a performance decrement by switching to a novel approach warrants further empirical analysis by comparing golfers with both prior BFA and prior TFA experience in a like study. Moreover, we appreciate that measuring performance with both final outcome (holed or missed putts) and with the use of combined distance and directional errors requires careful further consideration; it is an element of experimental design that has been poorly addressed within previous research analysing performance outcomes in target sports (see Fischman, 2015). Adding analyses of these variables to future study may provide greater insight to both theory and practice in sports skills development.

Practical implications. For the moment

It is worth noting that this is the first of several planned papers to explore the use of TFA. In this paper we have addressed some of the limitations of previous studies (e.g., high-level golfers using a real putting green with their own familiar equipment) and our data offer some interesting implications. For the moment it would be going beyond these data to make any concrete recommendations on, for instance, how coaches might use TFA with their clients, whether it is of benefit to yips effected golfers or the impact it may have on different skill levels of golfer. What is interesting is that, where previous work has recognised a distinct cost associated with the skill refinement process (Carson, Collins, 2016b), especially when not conducted in a careful and considered manner (cf. Carson, Collins, 2015; Toner, Carson, Collins, Nicholls, 2018), as an incomplete strategy TFA did not reveal any similar patterns of performance on first attempt. As such, for the sample tested here and from a distance of 8 ft., at least, we recommend that golfers might try TFA as a 'cost-free' experiment.

Conclusion

In conclusion, this study extends research into the use of TFA in golf putting and, in doing so, has responded to recent calls to address important omissions (Moffat et al., 2017). While there are still many more questions to be answered regarding this technique, data provide an informed stepping stone towards future investigations. Despite the general non-appeal of nonsignificant findings, it is important to understand *why* this is the case so that at the very least TFA does not become subject to misuse within the applied setting (Collins et al., 2015). Accordingly, this study has attempted to promote interaction between applied and basic research with the intention that each can inform the other (cf. Christina, 1987). For the moment, however, we await data that may illuminate the mechanism(s) involved during TFA. In light of recent perspectives on functional performance states and their psychological underpinnings (e.g., Bortoli, Bertollo, Hanin & Robazza, 2012; Swann, Keegan, Crust, Piggott, 2016), it seems that performance psychology could prove an appropriate and beneficial lens through which to direct these efforts. Finally, it remains

to be seen what would happen if high-level golfers committed to training with TFA for an extended period and what their perceptions are of the experience both during practice and competition.

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Cite this article as: Moffat, D., Carson, H.J., Collins, D. (2018). Golf Putting: Equivalent Performance with Ball Focused and Target Focused Aiming. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 5–16. DOI: 10.18276/cej.2018.3-01.

POLISH CONTRIBUTION TO THE DEVELOPMENT OF VIEWS ON HORSE RIDING AS A FORM OF THERAPY – A BRIEF HISTORICAL RETROSPECTION

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Abstract Since ancient times, man has ridden horses. Ancient Greeks and Romans, who did so mostly for utilitarian purposes, also found that horse riding was the source of rider's health, recommending equestrianism to men and women of different ages as an exercise that helped preserve a healthy body.

Poles, a nation whose history was always linked in a rather exceptional way with horses and horsemanship, realized quite early, at the beginning of the 17th century, that horse riding offered a variety of applications and could be used as a tool to improve human fitness and physical condition. Views of Polish hippologists such as Krzysztof Moniwid Dorohostajski and Marian Hutten-Czapski on health-related benefits of equestrianism gained popularity not only in Poland but also abroad. At the beginning of the 20th century, their opinions were endorsed by a Polish doctor, Władysław Hojnacki, who campaigned for horse riding to be used as therapy. After WW2, a distinguished Polish orthopedist and physiotherapist, Professor Marian Weiss introduced an innovative hippotherapeutic program at the Medical Center for Rehabilitation of the Locomotive Organs in Konstancin near Warsaw, finding many followers who helped hippotherapy to develop. Research confirmed that horse riding was indeed an effective form of therapy and this soon led to the establishment of the Polish Hippotherapeutic Society, organization of conferences and seminars providing a platform where views and research results could be exchanged, and starting a number of equestrian facilities across the country that popularized hippotherapy in Poland.

Key words horse, horse riding, hippotherapy, Poland

Introduction

People have ridden horses since ancient times. In the beginning, the horse played a primarily utilitarian role, helping the rider travel over long distances or transport goods. It was always a status symbol, a visible manifestation of importance and wealth of its owner. Later on, parallel to its original function, new ways of using the horse evolved – riding for pleasure, recreation, sport, or therapy. Generally speaking, each of these functions followed its own path but often – for the first time in the Antiquity, then in the 20th and 21st centuries – their elements intertwined producing hippotherapy, i.e. horse riding for therapeutic purposes and the equestrian sport for the disabled, as well as the

equestrian 'community', or 'family', a group of people for whom interaction with the horse and horse riding have become part of their way of life.

Views of ancient physicians and philosophers on the significance of horse riding

The first symptoms of interest in the advantages of horse riding and its positive influence on the rider maintaining, recovering and improving good health appeared as early as the Antiquity. Theories to that effect were put forth in several medical treatises by Hippocrates (about 460–370 B.C.), a Greek physician and father of modern medicine, whose name in Greek meant 'he who controls the horse' (Wyżnikiewicz-Nawracała, 2002). Other ancient philosophers, for example Plato (427–347 B.C.), shared Hippocrates' sentiment, encouraging adolescents, both male and female, to take up horse riding as a form of exercise: (…) *and women, too, should practice, in much the same manner. I would not fear to say this to you – one must not treat horse riding and gymnastics as occupations appropriate for men but, for some reason, inappropriate for women* (Kunicki, 2002). General references to the topic can also be found in the works of Xenophon (430–355 B.C.), for example *The Art of Horsemanship'* and '*Hipparchius*, although it is rather difficult to find in them more precise recommendations of the author and his contemporaries on the subject of therapeutic application of horse riding. Theories on the benefits of physical exercise, horse riding included, for human well-being and health were also endorsed and developed by one of the most eminent Roman physicians, a Greek by birth, Claudius Galenus (about 130–200 A.D.) (Lyons, Petrucelli, 1996).

Revival of interest in horse riding among physicians of modern times

Drawing on the experience of renowned members of the medical profession of the ancient world whose heritage in the form of numerous medical writings remained accessible in Italian libraries, many physicians of the modern era picked up and elaborated on the topic, arguing that horse riding could indeed treat a variety of ailments and improve human health and fitness.

In the 16th century, an Italian physician, Girolamo Mercuriale (1530–1606) studied the subject, publishing his findings in *De Arte Gymnastika* (1569). In his medical practice he applied his own therapeutic methods and laid foundations for modern physiotherapy. Others that followed suit were Thomas Sydenham (1624–1689), an English doctor, who published *Tractatus de podagra et hydrope* (1683), Francis Fuller (1670–1706), an English medical writer, who printed *Medicina Gymnastica* (1705), and Friedrich Busch (1844–1916), a German physician, who propagated his theories in *Allgemeinen Orthopadie, Gymnastik und Massage* (1882) (Wyżnikiewicz-Nawracała, 2002).

Views of Polish hippologists and physicians on the impact of horse riding on health and fitness of young people

To a substantial degree horse riding as a form of therapy was popularized by Polish authors, who argued that time spent in the saddle contributed greatly to the rider remaining in good health or, when necessary, recovering from illness. Polish culture, customs, and everyday life had always been rather uniquely intertwined with horses and horsemanship, and horse riding was seen as a particularly beneficial way of exercise. Encouraged to take to the saddle were people of all ages, even those decidedly past their prime. Longevity, which by no means was a widespread phenomenon in the 16th or 17th centuries, (for example, Mikołaj Odrowąż Pieniążek lived to be over eighty, or Helena Ogińska died at ninety), was attributed to the horsemanship skills of the long-living individuals and their regular engagement in horse riding. It was a generally held belief that the movement of the horse's back

under saddle improved the rider's blood circulation and muscular performance, a theory that came to be confirmed by scientific research several hundred years later. This deeply-rooted popular conviction that horse riding was an excellent health enhancer was also reflected in Polish folklore and language: *Good horse – healthy rider*, or *A good horse is half of one's health* (Hutten-Czapski, 1985; Sawicka, 2002).

A systematized body of knowledge on the subject was first promulgated in Poland by Krzysztof Moniwid Dorohostajski, Grand Marshall of Lithuania and hippologist. Having studied the matter abroad and travelled intensely, especially to and around Italy, he published the work of his lifetime in 1603. The book titled *Hippica – a Much Needed Treatise on Horses and a Joyful Reading for Men of the Sword, Published for Clarity of the Subject* was based on years of Dorohostajski's extensive experience and practical research. For more than 250 years to come it remained the most exhaustive Polish publication on all aspects of the use of the horse, emphasizing health-related advantages of horse riding (Dorohostajski, 2015). It was not until 1874 that Duke Marian Hutten-Czapski, renowned hippologist, bee-keeper, holder of a doctoral degree in law, and participant in the January Uprising of 1863, published in Poznan a three-volume *Common History of the Horse*, which he dedicated to 'the young generation' and supplemented with *An Atlas for the Common History of the Horse, Presenting in LXXV Charts Types of Horses from Various Countries and Everything that Has Always Concerned the Subject.* In it Czapski bore out and expanded the views expressed by Dorohostajski and other authors, foreigners included, stressing positive aspects of horse riding and benefits produced by practicing horsemanship. He wrote: *At the time, riding in the saddle was regarded to be an unfailing means of maintaining or recovering good health because, it was believed, the movements of the rider's body which the horse stimulated improved blood circulation. People also thought that the trot did good to infirm individuals, while the walk helped hypochondriacs* (Hutten-Czapski, 1985).

The second half of the 19th century saw a change in perception of horse riding and the role it played. It was no longer considered a mere necessity stemming from the need to travel, but gradually became more of a pleasant experience that the communing with a friendly mount and the trail invariably produced. A number of new sports emerged, for example cycling, rowing, fencing, skiing, skating, and, not surprisingly, horse riding. Other sports gained in popularity. Sports clubs and sports societies sprang into life, promoting sporty competition. Horse riding found new enthusiasts, not only in the countryside, where it had always been a natural form of physical activity, but also in towns, where it assumed more organized forms. 'Tattersalls' were set up across the country. Patterned after the original English race horse auctioneers, these were businesses that bought and sold horses but, most importantly, thought horsemanship to members of the general public. The Sokół Gymnastic Society, established in Poland in 1867, started several horse riding clubs where young people in cities and towns took riding lessons. By the end of the century, young riders had developed their own unique lifestyle characterized by physical activity, courage, and pursuit of a variety of interests, which, especially for female riders at the time, required much determination (Urban, 2003).

Involvement of women in the popularization of horse riding in general, and its therapeutic qualities in particular, became part of a broader emancipation movement of the turn of the 19th and 20th centuries. Its propagator in Poland was Maria Wodzińska (born in 1868), one of many female riders at the time, but the only one who did not hesitate to join the public discussion on the benefits of horse riding. Contrary to a widespread opinion that it was inappropriate for women to practice certain sports and that their physical activity should therefore be restricted, she encouraged women to learn to ride, arguing that horse riding exerted a beneficial influence on the body and had a variety of other advantages (Urban, 2000).

Maria Wodzińska proved to be a talented writer, too. She would publish newspaper articles about horse riding that were as charming as they were interesting and professional. In 1893 *The Amazon* was printed, the first and, for many years, the only Polish horse riding manual for female riders, in which the author elaborated on female health and the impact of the horse on maintaining and improving it. (…) *In England, France, and almost everywhere else, women tend to attain true perfection in this respect* [as riders]. *In Poland, it was not long ago that people thought it* [horse riding] *eccentric and would point the finger at ladies in the saddle.* (…) *Even today one can hear outraged voices criticizing women who decide to mount up and, apparently, run the risk of a voluntary death. Some critics even claim that of all dangers that a human being has to face in the course of their life, finding themselves in the saddle is by far the gravest! If you, ladies, only knew how horse riding, this most noble pastime, can revitalize the feeble body, the perturbed mind, and even the spirit, perhaps you would take to it more readily and encourage you children to do so as early as possible. In the past people wrongly believed that horse riding could ruin the health of not only married women, but maidens as well. Even today there are doctors who rigorously forbid their female patients to ride horses. Fortunately, there are many others who recommend it as an exercise that is very hygienic, if not downright therapeutic, since the movement of the rider's muscles in faster gaits bears a striking resemblance to massage, so popular today, oftentimes exceeding it in effectiveness* (Wodzińska, 1893).

Wodzińska's views, sound as they were, needed time to earn recognition among members of the general public. Although more horseman and horsewomen were seen taking pleasure rides in city parks and gardens, and the popularity of tattersalls and Sokół Gymnastic Society's riding schools rose, these were more the effects of changes in the lifestyle of the younger generation and sports becoming a new fashion than signs of true understanding of the therapeutic qualities of horse riding. Despite all her practical experience, Wodzińska was not a doctor or hygienist. Moreover, she was a women, which back then played a colossal role.

Yet the endeavors of the author of '*The Amazon'* do not go to waste, especially when the public debate on health-related advantages of horse riding was joined by Władysław Hojnacki (1869–1931), a doctor and gynecologist in Lviv. He was generally esteemed not only for his extensive medical qualifications but also practical experience. For many years Hojnacki was an active member of the Sokół Gymnastic Society in Lviv, which had run a riding club since 1894 (National Archives, Krakow). This gave him a first-hand opportunity to observe changes that occurred in the body of the rider who practiced horse riding regularly. Hojnacki took part in the International Congress of Physical Education in Paris, France, (March 17–20, 1913), wrote books and papers on sports and healthy lifestyle, and pioneered the notion of hygiene. Also, he was an ardent propagator of physical activity, especially among women and girls who, in a misguided effort to remain in good health, often chose to stay indoors without fresh air (Kozubal, 2017).

In his regular lectures on the impact of sports on human health, Doctor Hojnacki talked much more about the need for physical activity in women than men because he thought that one of the most (…) *neglected aspects is the balance between the mental and physical development of adolescent boys and girls,* (…) *where in truth every single, more vigorous, physical effort from a student must be explained, and then begged or clamored for. No wonder that twigs so bent, as it were, produce crooked trees – in other words, young people of today will most certainly turn into adults who won't not know how to exercise, nor will they exhibit any appreciation of the need for physical activity* (Hojnacki, 1905a). Hojnacki was determined to convince his contemporaries, especially the young ones, that practicing sports could prove beneficial to their health, and that it was an attractive and fashionable undertaking. Luckily, his efforts to that end were facilitated by fast-growing sports competition and a growing number of sports

events, for instance the Olympic games. Hojnacki believed that horse riding (…) *is a sport that ideally suits women, a beautiful sport, good for the physique and the morale, fit even for the more frail-bodied and delicate ones, and those who are recovering from illness; many doctors find it an effective means of therapy for their female patients* (Hojnacki, 1905a).

On April 15, 1905, on request of the Polish Society for Recreation of the Working Classes and the Young, Hojnacki gave a talk on the subject of horse riding as a sport and therapy. He started out by outlining the history of the horse under saddle, from the most remote times to his, and explained how riding a horse enhances human health. *There are many contributing factors, the first one being the movement of the body and the limbs of the rider, movement, mind you, which can range from passive shocks experienced by the rider on a quiet and composed horse in a slow gait, to increasingly intense motions, strains, and jolts that the rider must sustain or absorb, as the horse's speed picks up and his temperament becomes more palpable* (Hojnacki, 1905b).

Hojnacki argued that the pain the rider experiences in the thighs, the hips, the lower back, and other parts of the body, admittedly uncomfortable, should be seen as a positive symptom of muscular effort and, as such, a very beneficial experience. He pointed out, quoting physicians from other countries as well, that the rider's pulmonary system undergoes positive changes – breath deepens substantially and, in time, lung capacity increases. He stressed that horse riding demonstrated another invaluable characteristic – riding in parks and across country, which, according to Hojnacki, should ideally be embarked upon in the early morning, allowed (…) *one to delight in the beauty of nature at the break of the day* (…)*, which is an experience that exerts a positive impact on the entire nervous system, sets the right mood for the rest of the day, whets the appetite, and improves efficiency of whatever labors the rider intends to perform during the day* (Hojnacki, 1905b). He remarked that horse riding played an important social role, too, by providing an excellent opportunity for equestrians to make new acquaintances. It helped them stay in good mental health, energized their bodies, made them more courageous and able to react quickly to the changing surroundings, and, at the same time, thought them gentleness, patience, and affection towards a living animal.

At the beginning of the 20th century, continued Hojnacki, horse riding found a variety of health-related applications: for hygienic reasons it was recommended to people who performed work of cerebral nature; as recuperation enhancer, it was recommended to convalescents weakened by illness; as therapy, it was recommended to patients suffering from hysteria, neurasthenia, hypochondria, muscular atrophy, anemia, chlorosis, lack of appetite, digestive problems, uric acid diathesis, or obesity; and, prophylactically, against tuberculosis (that last correlation was identified through research and observation of French cavalrymen and infantry). In spite of the advantages he enumerated, Hojnacki warned novice equestrians against incompetent use of the horse, misjudgment of their own riding skills, and inability to choose the right horse for the rider's needs. He advised caution, i.e. medical consultations and assistance of an experienced riding coach. All in all, however, as an equestrian example to follow he held up the English high society, in whose opinion horse riding was (…) *the first dream of a virgin and the last joy of an old man* (Hojnacki, 1905b).

The inter-war years, i.e. the period between 1918 and 1939 spanning the two world wars, brought with it revolutionary changes in the riding seat, especially by female riders, and in the riding technique (Pruski, 1978, Urban, 2003). Research into the influence of horse riding on human health, both in Poland and abroad, continued. In 1930, upon a thorough analysis of available literature, a German country doctor by the name of Max Senator published a book titled *Health-Related Quality of Horse Riding.* In its final part, the author put a very sensible

sentence: *A true doctor must understand the art of dosing, that is to say, he must know the exact measures of his medications and auxiliary substances. This constatation applies also to horse riding* (Wyżnikiewicz-Nawracała, 2001).

Horse riding as a form of locomotor rehabilitation

Experience gathered over the years came in very useful in the 1940s and 1950s, when poliomyelitis, a disease against which no one had a vaccine yet, spread across Europe (an epidemic struck Poland in 1951, an recurred repeatedly in the following years) (Kwolek, 2014). The horse proved to be an effective weapon in fighting the disease, as was illustrated by the somewhat spectacular story of a Danish rider, Lis Hartel, who suffered from the spinal form of that disease, manifesting itself in flaccid paralysis of the lower limbs. Horse riding prescribed to Hartel as part of therapy produced effects that were positive enough to allow the young equestrian to return to active riding and win two silver medals in dressage at two consecutive Olympic games, in 1952 in Helsinki, and in 1956 in Melbourne (when horse riding events held in Stockholm). The achievements of the young Dane helped to propagate a general understanding that horse under saddle can be successfully used in therapy (*Porażenie dziecięce*, 1994; Sawaryn, 2008; Szabert, 2012).

It was in the 1950s that horse riding was introduced into the program of broadly understood locomotor rehabilitation. A number of organizations and societies supporting therapeutic equestrianism were set up, initially in Great Britain and Canada, later on in the USA and other countries. Finally, in 1976 in Basel, Switzerland, was held the first international congress on the treatment of various diseases (not only locomotor conditions) by means of horse riding (Szabert, 2012).

In post-WW2 Poland, equestrianism was not very popular, partly due to the politics of the new, communist regime which thought it a relic of the 'aristocratic' Second Republic. It was however much appreciated as a means of therapy. At first, horses were applied in therapy of visually impaired children at a medical center in Łódź by Doctor Buczkowski. Soon the idea was transferred to a medical facility in Konstancin, near Warsaw, which ran rehabilitation programs for patients with locomotive problems. In 1962, Professor Marian Weiss, head of the facility, introduced hippotherapy (from Greek 'hippos' – horse, and 'therapae' – therapy), an innovative solution at the time, to rehabilitate patients with orthopedic conditions, such as amputations or inborn limb reduction defects, valgus knees and hips, scoliosis, etc, neurological conditions (myelomeningocele, multiple sclerosis, poliomyelitis, etc), and problems of social and mental nature. The medical facility in Konstancin became famous for its hippotherapy programs and for almost twenty years to come remained the only Polish medical center offering that type of treatment (Schweitzer-Wirska, 2006; Polańska, 2003; Jandziś, 2014).

Despite evidently positive effects of hippotherapy on patients suffering from a variety of ailments, it proved difficult and time-consuming for the Polish medical community to embrace the concept of the horse being a generally acceptable rehabilitative instrument. In 1985, in Swoszowice near Kraków, on the initiative of Professor Stanisław Grochmala and Doctor Irena Solecka, horses from the local riding club 'Krakus' came to be routinely used to treat children from across the country that had been qualified for the therapy by doctors at the Regional Mother and Child Medical Center in Krakow. In their opinion (…) *the horse is a stimulus which speeds up treatment. The overall physical condition, coordination of body movements, and balance of our child patients improve dramatically. Their mental disposition is much better, too* (Pazdyk, 1988, Skorska, 1987).

A growing interest in hippotherapy called for increasing numbers of hippotherapists to be trained, which, as a result, led to the establishment new hippotherapy facilities. Equine-assisted therapy finally became recognized and appreciated by researchers and academics, but, most importantly, members of the medical world, who praised the benefits of this kind of approach to treatment. The then Chief Physician at the Rehabilitation Department of the City Hospital in Rzeszów, doctor Andrzej Kwolek remarked that (…) *the rhythm of the horse's movements* (…) *engaged in a natural way all the muscles, which, in patients with paralysis, was of paramount importance.* (…) *Contact with a friendly animal thought the children courage and faith in their own abilities* (Zaborniak, 2007; Przyszlak, Zaborniak, 2006). In 1992, in collaboration with the 'Zabajka' Horse Riding Club and as part of its organizational structure, the Rehabilitation Department started a hippotherapy section, one of the first few horse riding sections of this kind in the country.

The popularity of therapeutic horse riding continued to grow – so much so that a training course organized in 1987 in Krakow for equestrian therapists, trainers, and instructors was attended by over 50 participants from all over Poland, leading, in the subsequent years, to the foundation of new hippotherapy centers and new hippotherapy sections at horse riding clubs. Their operation was coordinated by the Polish Hippotherapeutic Society (or PHS) in Krakow, set up in 1992, which created a platform for cooperation between experts in a number of hippotherapy-supporting fields – doctors, physiotherapists, psychologists, learning coaches, horse riding instructors, horse breeders, etc. The number of riding facilities offering hippotherapy under the auspices of the PHS has been going every year (there were 21 in 2002 and 45 in 2018), an effect, no doubt, of several factors, such as the Hippotherapy for Disabled Children Foundation starting in Krakow, organization of academic conferences on the subject (the first one in 1992 called 'Hippotherapy – Theory, Practice, Potential'), and regular publication since 2006 of an academic quarterly 'The Hippotherapy Review' (Blichiewicz, Jackowski, Zrubek, 1988; Witkowska, 2006).

Conclusions

For centuries, horse riding was very popular in Poland. The horse was a prominent element of everyday life of all classes of the Polish society of yore. In time, it became an inseparable, revered and admired, part of national tradition and pride, and the greatest love of its owner. It was always seen as a reliable and loyal companion. Cavalrymen of the Second Republic used to say: *Before a maiden, the horse only.* After a brief period of communist 'disgrace', horse riding has been regaining its popularity with much vigor – it is now a form of recreation, an effective method of therapy, and a very important element of lifestyle of those who long to return to nature.

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Cite this article as: Urban, R. (2018). Polish Contribution to the Development of Views on Horse Riding as a Form of Therapy – a Brief Historical Retrospection. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 17–24. DOI: 10.18276/cej.2018.3-02.

EFFECT OF VARIABLE-INTENSITY RUNNING TRAINING AND CIRCUIT TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS OF SOCCER PLAYERS

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Abstract Proper planning of the training process based on individual LT[1] and AT[2] metabolic thresholds is essential to improve athletic performance. Development of endurance in soccer players is mainly based on continuous runs and variable-intensity runs, supplemented with strength conditioning and sport-specific training.

The aim of the study was to analyse selected parameters of physical capacity of soccer players after 8-week variable-intensity running training and circuit training.

The experiment was carried out in a group of 34 soccer players aged 21 to 26 years. The athletes were divided into two groups: 17 people in the experimental group and 17 people in the control group. The experimental group was involved in 30-minute tempo runs two times a week for 8 weeks with variable intensity at AT. In the same period, the control group performed two 60-minute continuous runs at the intensity of 70–75%HRmax. The determination of metabolic thresholds used two indirect tests: the multistage shuttle run test (beep test) and maximal lactate steady state test (MLSS) with author's own modification. In order to evaluate maximal heart rate (HRmax), the research procedure was started from the beep test (distance: 20 m). The speed at the first level was 8.5 km/h and increased with each level by 0.5 km/h.

Training of the experimental group where variable exercise intensity was used caused a statistically significant increase in HRmax (by 1.9%) and blood lactate levels at the AT (by 20.5%). The training in the experimental group led to the statistically significant ($p < 0.05$) increase in the parameters of the following variables: HRmax (by 1.9%); lactate level (by 7.85); HR at the AT (by 1,9%); lactate level at the AT (by 20.5%). The assumptions of the experimental training did not cause statistically significant

[1] LT – lactate threshold, where blood lactate levels are elevated over the resting levels.

[2] AT – anaerobic threshold, which is followed by a sharp increase in lactic acid build up.

changes in pretest vs. posttest HRmax and blood lactate levels for the LT. Endurance training with high intensity is more effective in soccer players compared to training with moderate intensity. Development of special endurance in soccer should also assume the intensity and method of working similar to the method used during sport competition.

Key words physiological parameters, soccer players, circuit training, variable-intensity running training

Introduction

A multifaceted and proportional improvement of individual motor abilities is critical to the process of motor preparation of athletes from team sports. Depending on the sport, a specific structure of motor development is used, determined by specific requirements of sport competition. Undoubtedly, all the team games are connected with the necessity of particular care for a high level of endurance.

In the case of soccer, which is characterized by work at high intensity, high level of endurance allows for performance of tactical actions and the use of technical skills over the entire match. Bangsbo (2014) analysed the energy systems engaged in soccer and demonstrated that the aerobic system was used in 70%, glycolytic system in 20% and the phosphagen system in 10%. The evaluation of the volume and intensity of the exercise in this sport leads to the conclusion that development of a high level of general and special endurance is essential in elite players.

The tools for evaluation of aerobic capacity in soccer players are used in the process of endurance development. Level of VO_2max, which reflects the level of aerobic capacity, determines athlete's endurance during sport-specific motor tasks. Proper planning of the training process based on individual LT and AT metabolic thresholds is essential to improve athletic performance (Hill-Haas, Dowson, Couts, 2010). Development of endurance in soccer players is mainly based on continuous runs and variable-intensity runs, supplemented with strength conditioning and sport-specific training. Skilful utilization of individual training methods using a specific configuration should be conducive to the improvement in physiological parameters.

The aim of the study was to analyse selected parameters of physical capacity of soccer players after 8-week variable-intensity running training and circuit training.

Material and Methods

The study participants were 34 soccer players from a first-league adult soccer team. The age of participants ranged from 21 to 26 years. Using a random number generator, the athletes were randomized into two groups (experimental and control), with 17 participants in each group. The experimental group was in involved in 30-minute tempo runs two times a week for 8 weeks with variable intensity at AT (Figure 1). In the same period, the control group performed two 60-minute continuous runs at the intensity of 70–75% HRmax.

After 4 weeks in the experimental group, the running time at the AT was elongated by 1 minute (Figure 1). Furthermore, both groups participated twice a week in circuit training sessions over the entire period of the experiment.

The experiment was approved by the Bioethics Committee at the Regional Medical Chamber No. 42/KBL/OIL/2015 as of 15 April 2015.

Metabolic thresholds were determined based on two indirect tests: multistage shuttle run test (beep test) and maximal lactate steady state test (MLSS) with author's own modification (Billat, 1996; Beneke, 2003; Billat, Sirvent, Py, 2003).

In order to evaluate the maximal heart rate (HRmax), the research procedure was started from the beep test (the distance used in the test was 20 m). The speed at the first level was 8.5 km/h and increased with each level by 0.5 km/h. With the increasing frequency of the beeps, participants moved on to increasing running speed and they covered the section at the faster rate. The test was continued to exhaustion i.e. the point when the athlete was unable to continue the test task. The heart rate was monitored using Polar Sport Tester. Immediately after exhaustion and athlete's refusal to continue the test, the heart rate was recorded as the HRmax and the blood lactate level was measured.

The MLSS test with the author's own modification was performed on the soccer field, where running sections were marked between the lines of the penalty area. The experiment started with the measurement of lactate level and a 3-minute run at the intensity of 60% HRmax. The lactate level was also measured after completion of the first stage. The next step was a 3-minute run with the intensity increased by 5% HRmax. In light of the values of maximum heart rates achieved by players, 5% HRmax represented the individual increase in running intensity by 9–10 HR/min. Similar intensification during the monitoring of the maximal constant HR was used by Vobejda. Fromme, Samson (2006). The procedure was successively repeated by increasing the intensity by 5% HRmax/3min until exhaustion. The pattern of frequency of blood sample collecting used in our study during performance of the MLSS protocol was also employed by Palmer, Potteiger, Nau (1999). Similar approach was used by Goodwin, Harris, Hernández (2007), who recommended the use of exercise intervals from 1 to 4 minutes. Regular monitoring of lactate levels at increasing intensity was used to indirectly evaluate the metabolic thresholds in athletes. The measurements were performed using the Lactate Scout analyser.

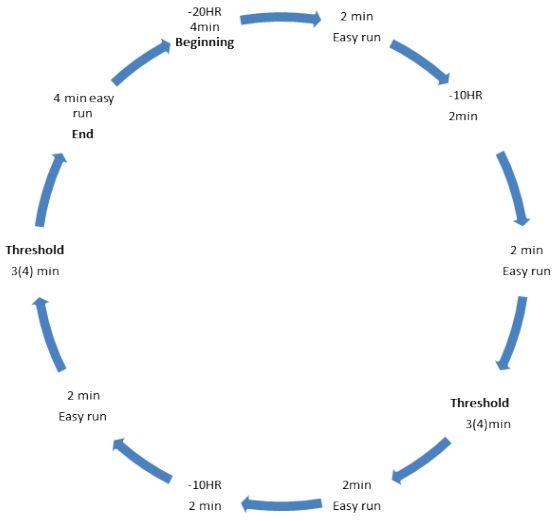


Figure 1. Design of the running training in the experimental group

Furthermore, both groups performed the circuit training sessions twice a week, comprising 10 general strength conditioning and functional exercises. With the same training volume, the experimental group used free weight exercises and body weight exercises while the control group performed only isolated exercises for individual muscle groups. The principle of alternate muscle work was employed in both groups, with particular focus on the muscles of the lower limbs. The assumptions for this training are illustrated in Table 1.

Table 1. Methodological assumptions for the circuit training for both groups

Circuit training using the equipment and free weights	
Number of circuits	3
Number of exercises in a circuit	10
Number of repetitions	15
Percentage of maximum weight	50%
Speed of performing the exercise	Fast
Rests between circuits	3 min

Statistical Analysis

The statistical analysis used 6 separate bivariate analyses of variance (group [training vs. control] × time [pretest vs. posttest]). Furthermore, the t-test for dependent variables and independent variables with Bonferroni correction was also used. Effect size was calculated based on partial eta squared (η^2_P), with its values of > 0.01, 0.06 and 0.14 corresponding to small, medium and large effect size, respectively (Miles, Shevlin, 2001; Cohen, 1988; Cohen, Cohen, West, 2003). The statistical calculations were performed using the STATISTICA ver. 11 software. For all comparison, the level of alpha for $p \leq 0.05$ was adopted as statistically significant. All the descriptive data were presented in the form of mean ± SD. In order to maintain transparency of presentation, the results in the figures were presented in the form of mean ± SE.

Results

Table 2 shows the results of the statistical analysis: mean values, percentage of changes in mean values, interaction values (group [training vs. control] × time [pretest vs. posttest]) and partial eta squared.

Figure 2 presents the difference in heart rate per minute, post-pretest with interaction with the level of LT and AT. Furthermore, Figure 3 shows a graphical representation of pretest-posttest lactate concentrations for HRmax, AT and LT.

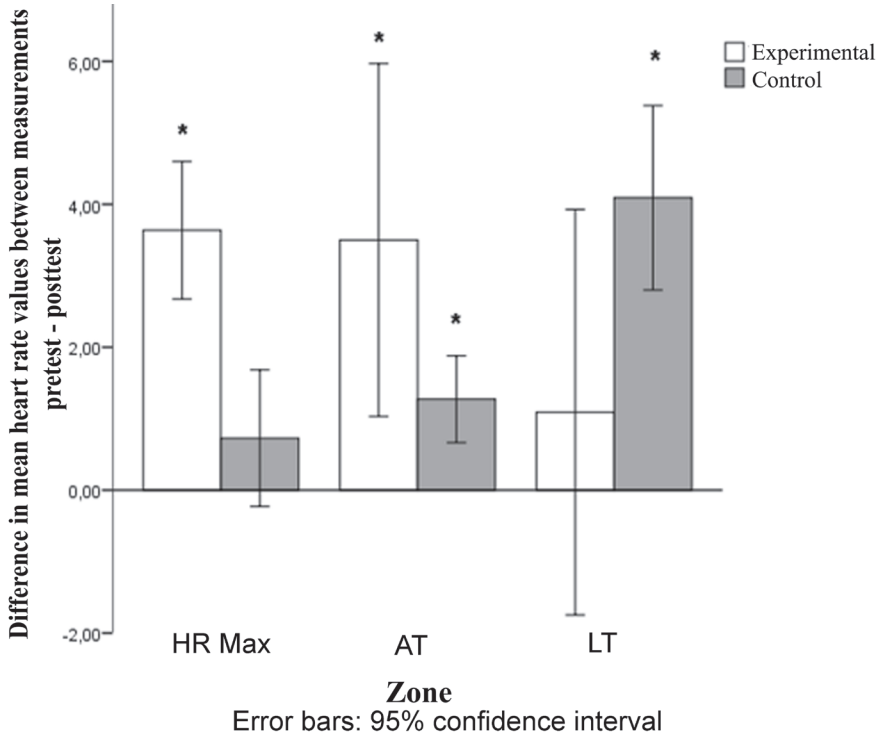
"The Normal Gaussian distribution of the data was verified by the Shapiro-Wilk's test. Homoscedasticity was tested by the Levene test."

Evaluation of the maximal heart rate (HRmax) revealed a significant interaction: group [training vs. control] × time [pretest vs. posttest] ($p < 0.001$). The analysis using the t-test for independent samples did not show statistically significant differences between the groups during pretest ($p = 0.775$) and posttest measurements ($p = 0.219$). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HRmax in the experimental group ($p < 0.001$). No statistically significant changes were found for this variable in the control group.

Table 2. Mean values, percentage of changes in mean values, interaction values (group[training vs. control] x time [pretest vs. posttest]) and partial eta squared

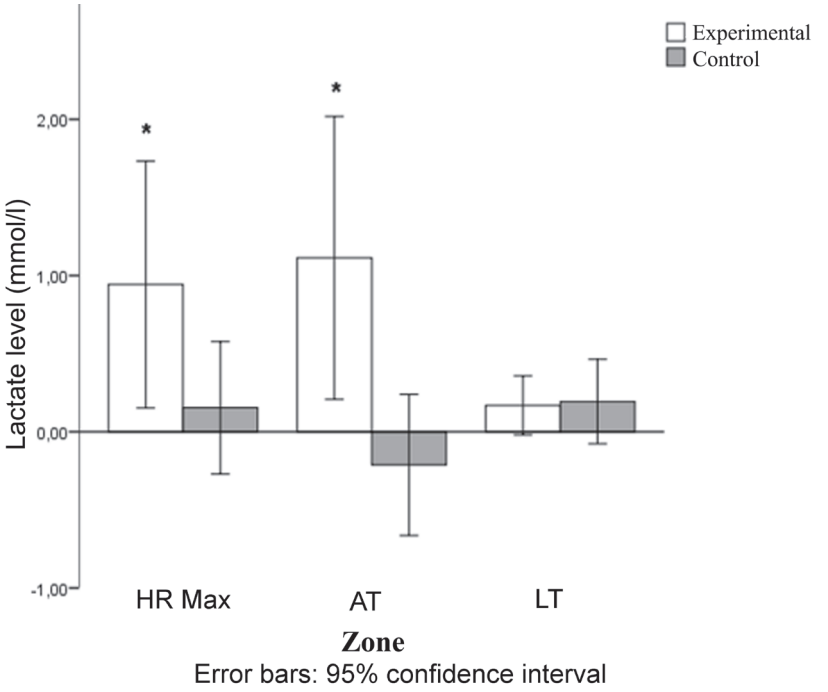
Variable		Control group		% change	Training group		% change	Interaction (p)	Partial Eta Square (η^2p)
		Pre	Post		Pre	Post			
HRmax (beats/min)		192.2 ±4.9	192.7 ±5.6	0.4	191.5 ±5.2	195.1 ±4.9‡	1.9	<0.001	0.342
Lactate levels (mmol/l)		12.7 ±0.9	12.8 ±1.2	1.2	12.0 ±1.6	13.0 ±1.9‡	7.8	0.167	0.061
Aerobic threshold zone	HR	180.0 ±5.9	181.3 ±5.8‡	0.7	180.9 ±5.9	184.4 ±9.5‡	1.9	0.201	0.052
	Lactate levels (mmol/l)	6.7 ±1.7	6.5 ±1.8	–3.1	5.4 ±1.3 §	6.5 ±2.0‡	20.5	0.046	0.123
Lactate threshold zone	HR	159.6 ±4.0	163.7 ±4.5‡	2.6	167.2 ±8.5§	168.3 ±4.5	0.7	0.141	0.069
	Lactate levels (mmol/l)	2.5 ±0.5	2.7 ±0.4	7.7	2.5 ±0.7	2.6 ±0.6	6.8	0.873	0.001

§ – intergroup differences pretest $p < 0.05$.
§§ – intergroup differences posttest $p < 0.05$.
‡ – intergroup differences pretest – posttest $p < 0.05$.



* statistically significant difference ($p < 0.05$) between pretest – posttest measurements.

Figure 2. The change in the post – pretest measurements of HR and lactate levels for the HRmax, AT and LT thresholds in the control and experimental group



* statistically significant difference (p < 0.05) between pretest – posttest measurements.

Figure 3. The change in the post – pretest measurements of HR and lactate levels for the HRmax, AT and LT thresholds in the control and training group

Blood lactate levels for HRmax did not reveal a significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.167). The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest (p = 0.775) and posttest measurements (p = 0.219). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest lactate levels for HRmax in the training group (p < 0.001). No statistically significant changes were found for this variable in the control group.

With respect to the AT for HR, the significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.201) was not found. The analysis using the t-test for independent samples did not reveal statistically significant differences between the groups during pretest (p = 0.226) and posttest (p = 0.832) measurements. The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HR for the AT zone in the training group (p = 0.001) (p = 0.008) and the control group (p = 0.001).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] (p = 0.046) was found for the lactate concentration in the AT zone. The analysis based on the t-test for independent variables showed a statistically significantly higher lactate levels in the AT zone in the experimental group at the point of pretest measurements (p = 0.021). However, no statistically significant differences were found for the results of the posttest measurements (p = 0.976). The t-test for dependent samples pointed to a statistically significant increase in pretest

vs. posttest lactate levels for the AT zone in the training group ($p = 0.018$). No statistically significant changes were found for this variable in the control group.

The interaction between the LT for HR did not reveal the significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.141$). The analysis using the t-test for independent variables showed statistically significantly higher values of HR for the LT zone in the training group ($p = 0.009$) for the pretest measurements. No significant differences were observed in the case of posttest measurements ($p = 0.155$). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest HR for the LT zone in the control group ($p < 0.001$) whereas statistically significant changes were not found in the training group ($p = 0.433$).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.001$) was found for the measurements of lactate concentration in the LT zone. The analysis based on the t-test for independent variables did not reveal statistically significant differences in lactate levels in the LT zone between the groups studied for both measurements. The analysis of t-test for dependent variables did not show a statistically significant increase in the pretest-posttest increase in the lactate level for the LT zone both in the experimental ($p = 0.077$) and control groups ($p = 0.142$).

Evaluation of the maximal heart rate (HRmax) revealed a significant interaction: group [training vs. control] × time [pretest vs. posttest] ($p < 0.001$). The analysis using the t-test for independent samples did not show statistically significant differences between the groups during pretest ($p = 0.775$) and posttest measurements ($p = 0.219$). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HRmax in the training group ($p < 0.001$). No statistically significant changes were found for this variable in the control group.

Blood lactate levels for HRmax did not reveal a significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.167$). The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest ($p = 0.775$) and posttest measurements ($p = 0.219$). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest lactate levels for HR_{max} in the training group ($p < 0.001$). No statistically significant changes were found for this variable in the control group.

With respect to the AT for HR, the significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.201$) was not found. The analysis using the t-test for independent samples did not confirm statistically significant differences between the groups during pretest ($p = 0.226$) and posttest measurements ($p = 0.832$). The t-test for dependent samples revealed a statistically significant increase in pretest vs. posttest HR for the AT zone in the training group ($p < 0.001$) ($p = 0.008$) and the control group ($p = 0.001$).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.046$) was found for the lactate concentration in the AT zone. The analysis based on the t-test for independent variables showed a statistically significantly higher lactate levels in the AT zone in the experimental group at the point of pretest measurements ($p = 0.021$). However, no statistically significant differences were found for the results of the posttest measurements ($p = 0.976$). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest lactate levels for the AT zone in the training group ($p = 0.018$). No statistically significant changes were found for this variable in the control group.

The interaction between the LT for HR did not reveal the significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.141$). The analysis using the t-test for independent variables showed statistically significantly higher values of HR for the LT zone in the training group ($p = 0.009$) for the pretest measurements.

No significant differences were observed in the case of posttest measurements ($p = 0.155$). The t-test for dependent samples pointed to a statistically significant increase in pretest vs. posttest HR for the LT zone in the control group ($p < 0.001$) whereas statistically significant changes were not found in the training group ($p = 0.433$).

A significant interaction of: group [training vs. control] × time [pretest vs. posttest] ($p = 0.001$) was found for the measurements of lactate concentration in the LT zone. The analysis based on the t-test for independent variables did not reveal statistically significant differences in lactate levels in the LT zone between the groups studied for both measurements. The analysis of t-test for dependent variables did not show a statistically significant increase in the pretest-posttest increase in the lactate level for the LT zone both in the experimental ($p = 0.077$) and control groups ($p = 0.142$).

Discussion

The results of this study lead to the conclusion that the planned training process yielded positive results. The improvement in the physiological parameters after the experimental period is likely to have been caused by new training stimuli which had not been used in the preparatory training of this soccer team. Claeesens, Lefevre (1992) find that the change in the physical activity may contribute to the improvement in motor effects and certain somatic changes in study participants. Based on the examinations, the authors hypothesized that the modified curriculum for physical education was one of the factors in achievement of better results in individual physical fitness tests.

Endurance tests demonstrated that the AT in the experimental group was statistically significantly moved to the right, with such a tendency observed in the control group only for the LT. This shows that the repeated training with high intensity at around the AT (which is typical of soccer) yields more favourable results in development of aerobic-anaerobic endurance. Denis, Fouquet, Poty (1982), who used training at the level of 85%VO_2max for 1 hour and 3 times a week over the initial 10 weeks of the experiment, documented the shift in AT by 10%. After 40 weeks, the authors found a total improvement by 18% and the increase in maximal workload (MWL) by 22%. Londeree (1997) found that training at the LT also yielded positive results. However, it represents insufficient stimuli for well-trained athletes, who need greater training intensity. This observation is consistent with the results recorded for the control group, where, in the context of variable exercise profile typical of soccer, the shift in the LT may not produce the favourable outcomes. Tabata, Nishimura, Kouzaki (1996) analysed the effect of a 6-week aerobic training at moderate intensity (70%VO_2max) and reported an improvement in VO_2max by 5 ml x min^{-1}x kg^{-1}, yet without a positive impact on anaerobic capacity. The author concluded that the improvement in both parameters should involve the increase in training work intensity. The results of the experimental group in our study, which demonstrated the shift in the AT, are partly consistent with this thesis and suggest an improvement in anaerobic capacity. No statistically significant changes in the indices of the LT were found. Denadai, Figueira Favaro (2004) analysed training of cyclists at the level of AT and found that the duration of the effort at this level while maintaining the steady state was not reflected by aerobic capacity.

In light of the results of our study, it can be concluded that training units should be intensified in order to induce the expected physiological adaptations. Helegerud, Høydal, Wang (2007) compared three types of training work oriented at improvement in physical capacity and demonstrated that training at the level of 85% HRmax at around anaerobic transitions yielded more favourable effect than the moderate-intensity training at 70% HRmax. However, it should be found that the third interval method, at very high intensity of 90–95% HRmax, demonstrated the most beneficial changes in capacity in study participants. It seems that the above study demonstrated a tendency for

changes in training work towards short-term exercise at high intensity. The findings of Gomreley, Swain, High (2008) are consistent with this observation. In a 6-week experiment in three study groups, the increasing work intensity was correlated with positive effects in development of $VO_{2max.}$. In three training groups where work intensity occurred at the levels of 50% Vo_2R, 75% Vo_2R and 95% Vo_2R, an improvement in VO_2max was observed (by 3.4, 4.8 and 7.2 ml × min^{-1} × kg^{-1}, respectively).

In our study, the lactate levels in the experimental group during reaching of the second AT after the training cycle revealed an improvement in athlete's body tolerance to presence of lactate during the exercise. This is conducive to e.g. elongation of working time at the level of maximal lactate steady state (MLSS) or the AT (Faude, Kindermann, Meyer, 2009). In light of the high correlation between MLSS and work performance in endurance sports (correlation coefficient: 0.92 with 8k run and 0.87 with 5k run), it seems justified to take this fact into consideration during selection of the training methodologies in the period of preparation to the soccer season.

In the period of the experiment, variances were introduced in the circuit training for 2 times a week. Many studies have demonstrated that the adequate resistance training positively supports the training process and intensifies its outcomes. In the aspect of supporting the endurance training, the effectiveness of circuit training was confirmed by Marcinik (1988) and Marcinik, Potts, Schlabach (1991). These authors found improvements in work performance on the cycle ergometer and a shift in the LT after a 12-week circuit training cycle performed 3 times a week. Similar phenomenon was observed in both soccer groups in our study, where circuit training was used with two different variants. Johnson, Quinn, Kertzer (1997) demonstrated that combination of strength training with capacity training yields enhanced motor effects compared to only capacity training. These authors showed not only the improvement in muscle strength (upper body muscle groups by 24.4% and lower body muscles by 33.8%), but also in the economy of muscular work during running. These phenomena were not recorded in the group with capacity training. It seems that the obtained outcomes of the author's own studies in both groups are also the effect of the supplementary strength training. It should be noted that the group that performed the high-intensity circuit training with free weights, which was based on the biomechanical nature of the muscular work typical of soccer, demonstrated more beneficial tendencies in the results obtained. It can be expected that the combination of free weight training with functional and sport-specific exercises may contribute to enhanced movement economy, which can yield more beneficial effects in control tests. Stanton, Reaburn, Humphries (2004) concluded that the choice of appropriate set of exercises that provide the adequate training stimuli may be of key importance in achievement of the goals. Karp (2010) argues that introduction of weight training induces activation of greater number of muscle tissues, which activates the nervous system. This improvement in sensitivity of receptors and facilitation of work of the neuromuscular system will presumably contribute to the improvement in work effectiveness in long-term efforts (work economy). Cotterman, Darby, Skelly, (2005) compared two types of muscular work using free weights or Smith machine and found that the first work was more efficient. In both cases of 1RM tests, the level of generated power (i.e. greater engagement in the muscular system) was better during barbell squat exercise and bench press. Shick, Coburn, Brown (2010) emphasized that coaches should note that the free weight strength conditioning is conducive to improved activation and effectiveness of muscular work compared to isolated machine workout. These observations should be taken into consideration during the choice of exercises for soccer players. Soccer training engages the entire kinematic chain of muscular work. Physical preparation should involve the exercises that require synergy and high activation of muscle groups. Hoff, Helegerud (2004) argue that the contemporary training work in soccer is based on the conglomeration of endurance and strength conditioning. As observed by these authors,

both forms of work translate into high intensity of exercise. These observations are consistent with the results of our experiment, where we found more beneficial physiological parameters in the experimental group, engaged in high-intensity training sessions compared to the group of players where the intensity of exercises remained at a moderate level.

Conclusions

The assumptions of the experimental training performed in the 8-week training of soccer players contributed statistically significantly to the improvement in the following physiological parameters:

1. Compared to the results documented for the control group, training of the experimental group where variable exercise intensity was used caused a statistically significant increase in HRmax (by 1.9%) and blood lactate levels at the AT (by 20.5%).
2. The training in the experimental group led to the statistically significant increase in the parameters of the following variables: HRmax (by 1.9%); lactate level (by 7.85); HR at the AT (o 1,9%); lactate level at the AT (by 20.5%).
3. The assumptions of the experimental training did not cause statistically significant changes in HRmax and blood lactate levels for the LT in soccer players examined in the study.

The results of the experiment lead to the following conclusions of practical importance to planning the process of preparation in soccer:

1. Endurance training with high intensity is more effective in soccer players compared to training with moderate intensity.
2. Development of special endurance in soccer should also assume the intensity and method of working similar to the method used during sport competition.

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Cite this article as: Ambroży, T., Nowak, M., Omorczyk, J., Wrześniewski, K., Ozimek, M., Duda, H., Mucha, D., Ceranowicz, P., Pałka, T., Stanula, A., Mucha, D. (2018). Effect of Variable-Intensity Running Training and Circuit Training on Selected Physiological Parameters of Soccer Players. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 25–35. DOI: 10.18276/cej.2018.3-03.

A PROFILE OF SYDNEY WORLD MASTERS GAMES ATHLETES: HEALTH, INJURY AND PSYCHOLOGICAL INDICES

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Abstract The World Masters Games (WMG) are an international, multi-sport event which, in terms of competitor numbers, is the world's largest. The purpose of this manuscript was to summarize research to date that has been conducted on the WMG cohort. This paper also reports a descriptive and analytical overview of this large sample to document aspects of demographics and health indices for this population. Masters athletes demonstrated significant improvements in health related indices over age matched comparative national populations. Notable among these improvements were body mass index and cardiovascular disease (CVD) risk factors for the majority of participants, with female WMG participants presenting improved scores for CVD risk factors (blood pressure and high density lipoproteins, $p < 0.05$) and body mass index ($p < 0.05$) when compared to males. There were also improved lifestyle behaviors such as reduced smoking. A concern was improved health indices might be negated by increased injury from competitive sport at older ages, however findings did not support the premise of masters football code athletes having higher incidence of injury compared to younger athletes. With improved health indices associated with masters competition, it is relevant when promoting physical activity at older ages that the most motivating factor behind participation was socialization with others.

Key words Masters Sport, healthy aging, Quetelet index

Introduction

As defined by Raeburn and Dascombe (2008), masters athletes are those systematically training for and competing in organized sporting events designed specifically for older adults. Governed by the International Masters Games Association, the World Masters Games (WMG) are a non-invitational, quadrennial, international, multi-sport

event. In terms of competitor numbers, the WMG has developed into the world's largest international sports event. The Sydney World Masters Games (SWMG) attracted 28,089 competitors who represented 95 countries competing in 28 sports (Sydney WMG Committee, 2010). In fact, the largest ever attendance at a WMG event was in Sydney, making this the largest international sporting competition (in terms of participant numbers) in the modern era. Participation at the WMG is open to sports people of all abilities and most ages, the minimum age criterion ranges between 25 and 35 years depending upon the sport.

The benefits of participation in masters athletic competition had been previously investigated with Hawkins and others reporting positive adaptations in musculoskeletal health (Hawkins, Wiswell, Marcell, 2003; Feland, Hager, Merrill, 2005; Seals et al., 1984; Whiteson, Bartels, Kim, Alba, 2006), improved glycaemia (Rogers, Kind, Hagberg, Ehsani, Holloszy, 1990; Pratley, Hagberg, Rogus, Goldberg, 1995) and considerable health benefits associated with the long-term exercise participation (Franklin, Fern, Voytas, 2004; Rosenbloom, Bahns, 2005; Shephard, Kavanagh, Mertens, Qureshi, Clark, 1995). Although long-term participation in sport (and physical activity (Olejnik, Kubińska, Pańczuk, Kubińska, 2017)) is advocated by health professionals, the advanced age of participants is also commonly associated with an increased incidence of chronic diseases such as coronary artery disease (Chugh, Weiss, 2015; Shapero et al., 2016), hypertension (HTN), hypercholesterolemia, and diabetes (Whiteson, Bartels, Kim, Alba, 2006). Although the WMG have been in existence since 1985, surprisingly there was limited scientific literature available on this specific cohort. An international team of researchers was thus formed to investigate the nexus between aging, physical activity, indices of health and the global obesity epidemic by investigating those competing in masters sport. The team investigated over 8,000 masters athletes competing at the 2009 Sydney WMG. The Sydney WMG was the largest sporting event by participant numbers and a high number of competitors took part in the research survey. It is therefore even possible this is the largest research survey (in terms of competitor numbers) ever conducted at a competitive sporting event.

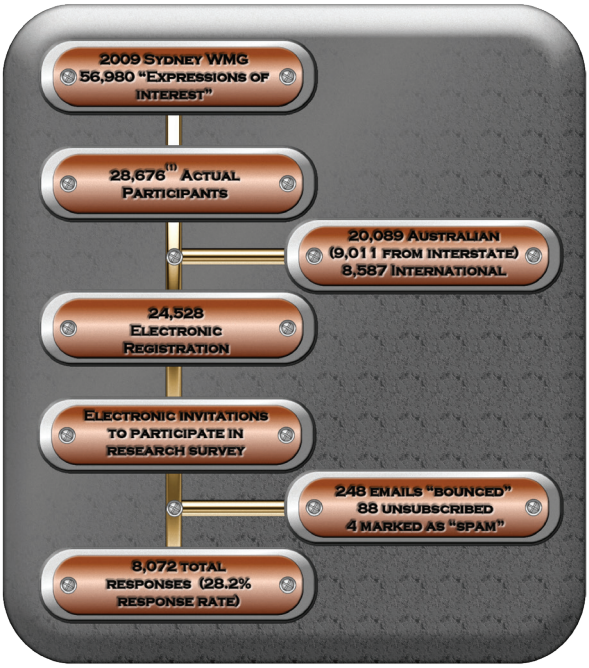
Research Purpose

The purpose of this manuscript was to summarize key research to date that has been conducted on the WMG cohort, not only a unique and interesting population with relevance to such health concerns as the global obesity epidemic, but also possibly the largest ever sample of competitors from a competitive sports tournament. This paper also provides a high level descriptive overview of the WMG cohort to document various aspects of demographics and health indices for this population.

Methodology

Approval for this study was granted by a university Research Ethics Committee in accordance with the ethical standards of the Helsinki Declaration of 1975 (revised in 2008). The 2009 Sydney World Masters Games Organising Committee approved the project, stipulating the survey must only be provided in an online format so there was minimal disruption to the WMG participants during the WMG. An online survey was created using Limesurvey^{tm}, an open-source, web based application to deliver the survey. Filters were used in the participant questionnaires to abbreviate response times. Following pilot testing by investigators, electronic invitations were sent to masters games athletes who provided a valid email address upon registration. The survey consisted of several sections. These sections featured questions related to the following areas: information for participants, a privacy statement, participant demographics, participant medical history (personal and family), past surgical procedures, prescribed

medications, physiologic data and psychological participation factors. The Sydney WMG Survey Process is displayed in Figure 1.



(1)Total participants 28.676 (Sydney WMG Committee, 2010).

Figure 1. 2009 Sydney WMG Survey Process

Summary statistics and analyses for the Sydney WMG masters athletes sample

This section of the manuscript contains a high level descriptive overview, with some summary analyses for the masters athletes at the SWMG.

Population Pyramids

To get an overview of the study participants, population pyramids were generated to examine the distribution of athletes across the whole sample and also the top five sports (ranking by competitor numbers). The WMG sample population pyramid for the dataset (mean age (yrs) 51.6 (+9.9, range 25 to 91), split by gender (males mean age 53.7 +10.0 years, range 25 to 91 and females (mean age 49.9 +9.1 years, range 26 to 91) is shown in Figure 2. The population was fairly evenly divided with 51.5% of the masters athletes male and 48.5% female.

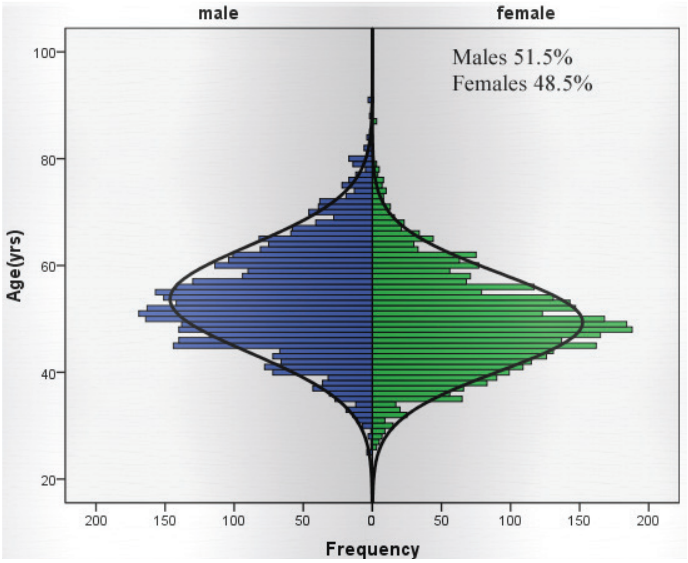


Figure 2. Population pyramid displaying participation demographics by gender. Line of normality displayed

The most represented nation in the survey was the games host nation, Australia. As demonstrated in Table 1, the five most represented countries in the survey provided the majority of participants (94.9%).

Table 1. Distribution of participation by country for the five most represented countries

Participation Rank	Country	Participation by country	Percentage of total competitors
1	Australia	5,260	74.9
2	Canada	695	9.9
3	New Zealand	322	4.6
4	USA	233	3.3
5	UK/Great Britain	151	2.2

A total of 28 different sports were played at the games with a number of the sports having multiple subcategories. Population pyramids by gender for the top five sports most represented in the survey are shown in figures 3–7. Figure 8 shows the population pyramid by gender for the remaining sports at the games.

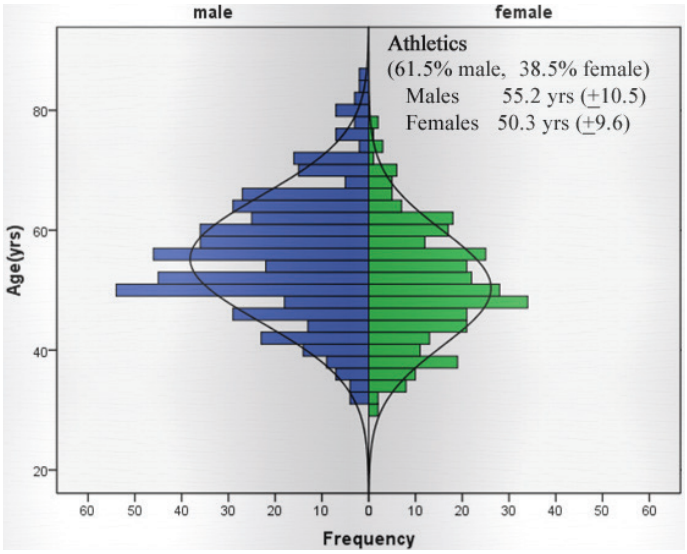


Figure 3. Athletics, 10.2% of participants

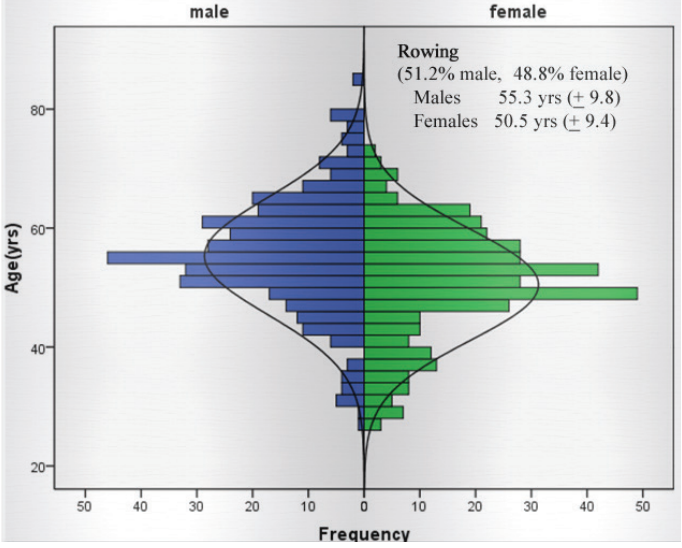


Figure 4. Rowing, 9% of participants

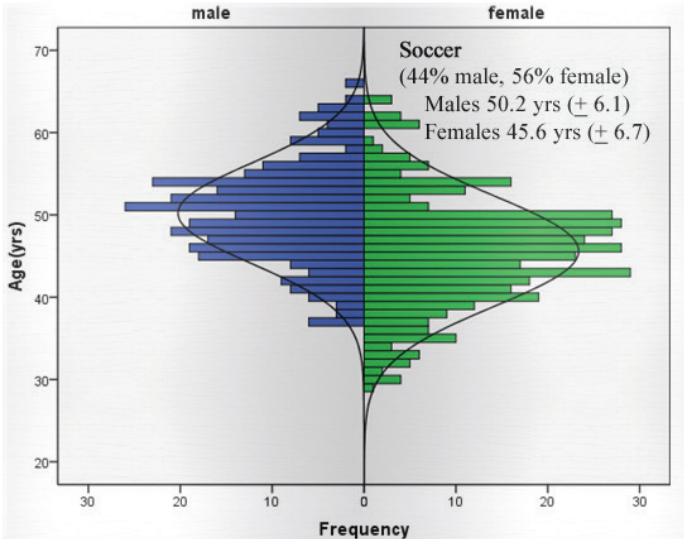


Figure 5. Soccer, 9% of participants

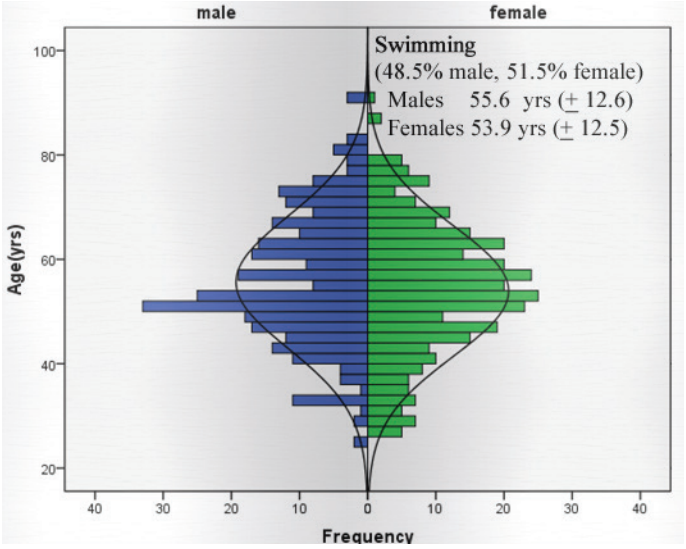


Figure 6. Swimming, 9% of participants

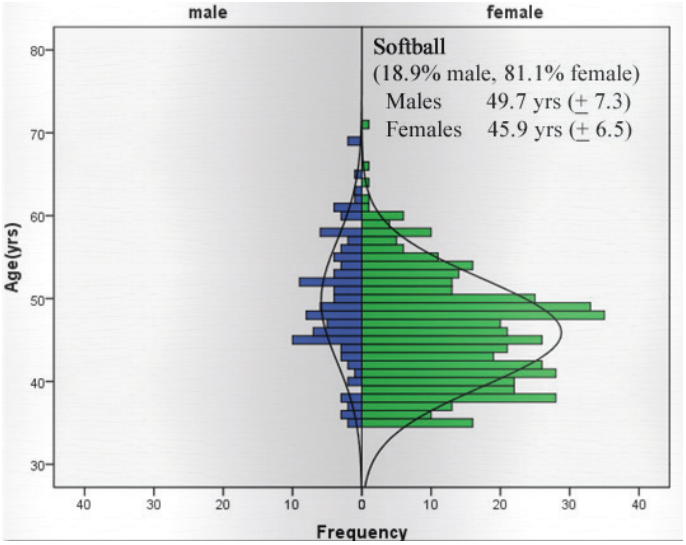


Figure 7. Softball, 9% of participants

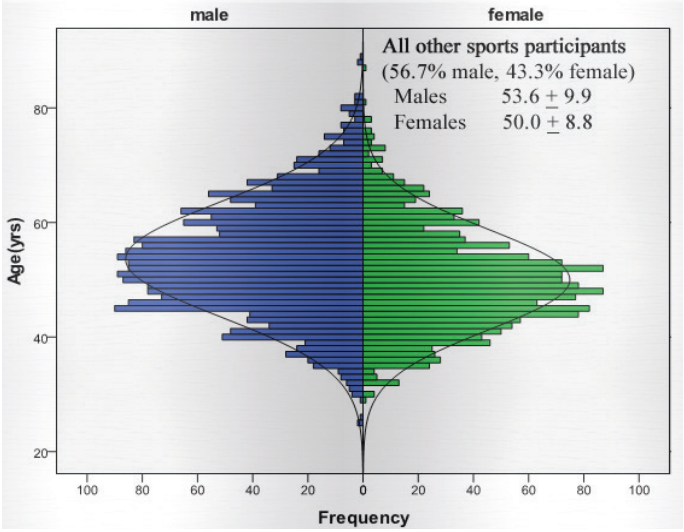


Figure 8: All "other" sports participants

Given the majority of competitors were from Australia (Table 1) and running, swimming and soccer were among the most popular sports in Australia (Australian Bureau of Statistics, 2010), it is unsurprising that the most popular sports included soccer, swimming and athletics (which encompasses a number of distinct field disciplines as well as track/running disciplines).

Chronic Disease, health and injury summary statistics

Summary statistics for key chronic disease and important health summary statistical data are reported in this section for the WMG athletes. The incidence of chronic disorder, surgical procedure, use of prescribed (Rx'd) medications (HTN, hypolipidemic, nonsteroidal anti-inflammatory drugs (NSAID), bronchodilators), as well as the type and nature of injuries sustained during preparation for the games are represented in Table 2. The impact of injuries was also examined. For those participants that sustained injuries in preparation for the SWMG, those injuries resulted in an average of 47.4 days off training (range 1 to 1,100) and an average of 17.6 days off work (range 1 to 400).

Table 2. Incidence of chronic disorder, surgical procedure, Rx'd medication, injury (type and locale)

		Population Incidence (%)	Male (%)	Female (%)	(Pearson) Chi-Square Statistic
Chronic Disorder	HTN	9.5	60.1	39.9	25.6**
	Rheumatoid and Osteoarthritis	8.9	46.9	53.1	6.9**
	Asthma	8.7	41.2	58.8	33.3**
	Hyperlipidemia	6.4	65.2	34.8	42.8**
	Depression	6.3	39.1	60.9	33.5**
Surgical Procedure	Knee replacement/repair	10.3	52.0	48.0	0.1
	Hernia repair	5.8	80.6	19.4	169.0**
	Shoulder repair	2.3	65.6	34.4	14.8**
Prescribed Medication	HTN	7.4	61.9	38.1	28.9**
	Hypolipidemic	4.9	68.1	31.9	49.7**
	NSAID's	6.4	43.7	56.3	9.8**
	Bronchodilators	4.0	39.8	60.2	18.2**
Injury (type of injury)	Muscle/tendon	9.4	61.6	38.4	34.5**
	Joint pain	5.4	58.8	41.2	9.7**
	Inflammation	4.6	53.9	46.1	0.9
	Muscle pain	4.6	58.3	41.7	7.1**
Injury (location)	Legs	6.7	66.7	33.3	54.2**
	Knee	4.9	53.2	46.8	0.5
	Shoulder	3.1	56.5	43.5	2.5
	Spine/back	3.0	61.3	38.7	9.6**
	Ankle	2.7	58.6	41.4	4.5*

* = $p < 0.05$ and ** = $p < 0.01$, indicate significant differences between genders.

Data on lifestyle behaviours such as smoking and drinking was also gathered for the masters athletes. A total of 3.6% of the survey participants were smokers, whilst 17.7% were ex-smokers. Amongst the smokers, the average number of cigarettes per week was 79 (range 1–279). This value is slightly lower (–12.5%) than the

average consumption of adults in Australia (88.9 cigarettes/wk) (Greenhalgh, Scollo, Bayly, 2017). A total of 73.5% of the survey participants consumed alcohol, with an average consumption of 6.8 standard alcoholic drinks per week whilst 0.8% of participants identified themselves as ex-drinkers. This consumption is well below (–116%) the Australian average of 14.7 standard drinks per week (Australian Bureau of Statistics, 2017).

Summary of published findings to date

In addition to the summary statistics and analyses on the SWMG athletes, further research has involved more granular analysis of this large cohort. Findings to date have furthered the understanding of the complex nexus between aging, physical activity, sports injuries, psychological factors associated with sports competition, health and obesity. Findings published in the literature are summarized in following sections.

Body mass index and obesity

WMG athletes demonstrated significant improvements in various health related indices compared to control groups (including an age matched comparative national population obtained via a data sharing agreement with the Australian Government Australian Bureau of Statistics). Notable among these improvements for masters athletes were body mass index for the majority, but not all participants. Research on SWMG swimmers (9% obese vs. 21% obese as adult national average for Australia) (Walsh et al., 2013b), basketballers (13.2% obese) (Walsh et al., 2013a), soccer players (9.1% obese) (Walsh et al., 2012a) and other football code athletes (11.8% obese overall, though 34.3% specifically for male rugby players) (Walsh et al., 2011a) overall demonstrated positive findings.

Due to the large number of participants, these sub-samples of athletes can be considered as representative samples of their sports at the SWMG. Results identified that body mass index (BMI) lay significantly more in the range considered as normal for masters athletes, as compared to a large general population of adult Australians. This finding indicated significantly improved health in terms of one health risk factor for WMG athletes compared to adult Australians. The significant improvement ($p<0.001$) persisted across seven comparative national populations (for the U.K., summary statistics for three separate populations from each of England, Scotland and Wales were used). It was therefore appropriate to consider that the BMI of WMG athletes was lower than the general population from the constituent countries and that there was not significant causation by nationality for Australia.

Whilst comparison to several international populations was made, it was the Australian population that was of most relevance. The majority of athletes were from the Australian population (74.9%), therefore this population was most applicable, however comparison to the other national populations was made in order to eliminate the possibility of some erroneous effect due to the WMG population being of mixed nationalities. As these other national populations were surveyed in a variety of ways (self-administered questionnaires, investigator administered questionnaires, physical measurements or combinations of these methods) care was taken when comparison was made to the self-administered questionnaire-based data on the WMG athletes. For this reason the Australian Bureau of Statistics (ABS) data using a self-reported heights and weights was appropriate to use, however the trend in difference ($p < 0.001$) persisted regardless of sampling procedures used in data collection.

Differences in BMI between the different sports at the Sydney WMG games was also investigated. Walsh et al. (2012d) compared BMI for 6,071 masters athletes across all 28 sports at the Sydney WMG. Differences in obesity prevalence were identified between sports (e.g. orienteering 2.51% obese vs. archery 39.13% obese). This may have indicated higher risk for conditions such as type 2 diabetes or heart disease in masters archery,

shooting, rugby union, softball and baseball (Walsh et al., 2012d). However, it was indicated that there are other complex differences between the sports, including differences attributed to increased muscle mass, which would make it inappropriate to make recommendations of preferential participation solely on these findings for one index associated with health (Walsh et al., 2012d). Coaches of those sports demonstrating increased obesity prevalence were recommended to consider additional weight management strategies in their training regimes, particularly if there is no sporting benefit from increased BMI (Walsh et al., 2012d).

BMI is an important factor in the chronic disease burden within a population. Various studies have identified many characteristics and biochemical parameters as being significant factors behind obesity and elevated BMI (Das, 2011), requiring a multifaceted approach to alleviate the current obesity pandemic. Given the complexity of this problem and its connection to inactivity, these findings on this unique cohort of individuals were of special interest.

For a large representative sample of 6,071 athletes competing at the Sydney WMG, it was shown that for both male and female athletes, as well as for the sample as a whole, the more common trend of higher prevalence of higher BMI with increased age was reversed (Walsh et al., 2011b). Results of polynomial loess regression were closely matched to those of linear regression for the bulk of observational values (40–80 yrs) and showed further reduced BMI predictive values outside this range, though these areas were not as reliable for predictive purposes due to the lower density of observational readings in these areas (Walsh et al., 2011b). Despite a visually altered array of observational readings across the two genders, consistent negative gradient linear regression lines, as well as consistent loess regression curves were very encouraging results and confirmed the pattern within the data as being more reliable and non-gender specific on a macroscopic level (Walsh et al., 2011b).

Smoking

Smoking is one of the biggest public health threats and a prominent risk to health globally. Smoking is the most significant lifestyle behaviour as a cause of preventable death. Most prominent of the negative effects of smoking and passive smooking are associated cancer risks. However there are a myriad of negative effects both in terms of health and also social and economic disadvantage. Comparison was made between masters athletes competing in football codes (rugby unon, soccer, touch football) at the world masters games and data from the Australian Bureau of Statistics on smoking prevalence (Walsh et al., 2012b). In context of the popularity of the various football codes in Australia it was interesting to consider the smoking status of Sydney WMG athletes. It was hypothesised that improved lifestyle behaviours would be demonstrated by masters athletes. Smoking prevalence was lower than global (World Health Organisation) and Australian (ABS) comparitive data. It was possible that improved lifestyle behaviours might have contributed to improved economic status and health, allowing competition at older ages (Walsh et al., 2012b).

Cardiovascular disease risk

Cardiovascular disease (CVD) risk in Sydney WMG athletes was investigated for significant differences between 1,435 Sydney WMG masters athletes (567 female and 868 male, aged 27–91 years) and the Australian adult population (Debeliso et al., 2017). CVD data was gathered, including data on waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP), high-density lipoprotein (HDL), low-density lipoprotein (LDL) and total cholesterol (TC). Key findings included significant differences between genders with females

significantly lower in BMI (–5.3%, $p < 0.001$), WC (–10.6%, $p < 0.01$), resting SBP (–5.8%, $p < 0.01$), resting DBP (–8.4%, $p < 0.01$), significantly higher in HDLs (+15.2%, $p < 0.001$) and significantly lower in both the TC:HDL ratio (–12.6%, $p < 0.001$) and LDL:HDL ratio (19.0%, $p < 0.001$). Significant differences ($p < 0.001$) were also identified when comparing WMG lipid results to the Australian general population (Australian Bureau of Statistics data for adult Australians). WMG demonstrated clinically superior TC (4.47 ±1.11 mmol/L), HDLs (1.75 ±0.79 mmol/L), and LDLs (2.92 ±0.96 mmol/L) when compared to Australian general population parameters (TC: 5.07 mmol/L, HDL: 1.34 mmol/L, LDL: 3.13 mmol/L). This provided increasing evidence of improved health in masters athletes. WMG participants demonstrated improved values in a number of CVD risk factors when compared to the general population with female WMG participants presenting improved scores for CVD risk factors when compared to males. Hence, within the parameters of DeBeliso et al. (2017) Sydney WMG masters athletes exhibited evidence of superior health when compared to the general population within Australia.

North American masters athletes at the Sydney WMG

Further investigation was conducted focusing on North American Sydney WMG masters athletes (n = 928, age 52.6 ±9.8 yrs) identifying as representing USA or Canada (DeBeliso et al., 2011; DeBeliso et al., 2014). Chronic disease and disorder indicators reported by participants were significantly lower versus the general US population. Very few (2.5%) reported currently smoking with an average of 65 cigarettes per week, while 13.6% were ex-smokers. Alcohol consumption (82.0% of the participants) averaged 4.7 drinks week, while 0.6% were ex-drinkers. The top five chronic disorders were rheumatoid arthritis or osteoarthritis (10.0%), hypertension (HTN 9.1%), hyperlipidemia (8.0%), asthma (6.5%), and depression (5.3%). Top three operative treatments were knee replacement or repair (12.2%), hernia repair (6.1%), and herniated disc surgery (2.0%). Top four prescription medications were anti-HTN (6.9%), thyroid hormones (6.6%), hypolipidaemic (6.0%), and medications to increase bone strength (5.9%). Prevalence was significantly lower versus the general US population for HTN, hyperlipidemia, arthritis, asthma, and depression (all p-values <0.01).

DeBeliso et al. (2014) investigated the BMI of North American Sydney WMG competitors with respect to national health guidelines and demographics. A total of 928 (46.7% male, 53.3% female) participants from Canada and the United States (aged 52.6 ±9.8 years) completed the survey. The top 5 sports in which participants competed were football (25.6%), track/field (15.4%), swimming (8.4%), volleyball (8.2%), and softball (7.8%). Female and male BMI (kg/m^2) across all sports were: >30 kg/m^2 (obese: 13.9%), 25.00–29.99 kg/m^2 (overweight: 34.1%), 18.50–24.99 kg/m^2 (normal: 50.3%). The prevalence of obesity was significantly lower ($p < 0.05$) for North American WMG competitors when compared to Canadian and US populations.

Injury patterns

Despite potential benefits for masters athletes in terms of reduced incidence of chronic disorders and improved indices of general health, there was concern that due to age related changes, increased risk of injury would be associated with highly competitive sport for the aging athlete. For masters football athletes at the Sydney WMG, the injury incidence during preparation for the tournament has similarities to, but was in fact shown to be significantly less than for other competitive sporting populations (Walsh et al., 2013c). Some gender and sport based differences in injury location and classification type were identified between different football codes (rugby union, touch football (a high participation sport in Australasia, see Walsh, Heazlewood, Climstein, 2012e)), soccer) (Walsh et al., 2013c).

There were also no significant age related changes in injury nature (classification type, location, incidence, time off work or training) (Walsh et al., 2013c). Therefore the premise of masters football code athletes having a higher incidence of injury as compared to younger athletes was not supported (Walsh et al., 2013c). Further research (Heazlewood et al., 2017) conducted on 7,175 Sydney WMG masters athletes, rank ordered the injury data to compare male and female masters athletes. The rank order of injury location was similar for males and females with the highest ranked injury location being knees or legs. The rank order of injury classification was also similar for males and females with the highest ranked type of injury being a muscle or tendon strain. Injury rates were relatively low for females ranging from concussion (0.1% of injuries) to muscle or tendon strain (8.4%). For males the injury rates ranged from dental or puncture injuries (both 0.1% of injuries) to muscle or tendon strain (12.6%). Climstein et al. (2012) investigated the injury incidence in three diverse, but well represented sports soccer, rowing and swimming at the Sydney WMG. Results demonstrated differences injury patterns between the three sports in terms of location and consequences of the injuries. The injury consequences were measured in terms of days of work and training lost due to the injuries. Climstein et al. (2012) concluded that the incidence of injury was not sufficient to warrant a suggestion to not participate due to injury risk. This finding, similar to Walsh et al., (2013c), was considered a positive result due to the evidence health benefits from exercise.

Pyschological motivations for competition

With evidence of improved health indices associated with masters competition, it was logical to investigate factors connected with motivation to compete in masters sport. A section of the Sydney WMG survey tool incorporated 56 questions from a psychometric tool the motivations of marathoners scales (MOMS) (Masters, Ogles, Jolton, 1993). This was selected as past WMGs participants had age ranges with significant overlap to the age ranges used to develop the MOMS survey instrument. Additionally the items identified in the MOMS had been demonstrated in other studies (Ogles, Masters, 2003; Havenar, Lochbaum, 2007) as important motivational constructs.

Socialization with other participants was the most important personal motivation for masters sport participation (Adams et al., 2011; Heazlewood et al., 2011). Health and fitness were less important motivators than socializing to these masters level participants, but still stronger than motivating factors associated with competition (Adams et al., 2011; Heazlewood et al., 2011). Particularly notable was that as body mass index increased, masters athletes were more likely to be motivated by socialisation as opposed to weight loss (Walsh et al., 2012c), a finding that could influence marketing initiatives to increase exercise participation at older ages for obese participants. Sevene et al. (2012) examined 1,824 Sydney WMG athletes to determine if their motivations to compete were primarily intrinsic or extrinsic. Masters athletes at the Sydney WMG were equally motivated by intrinsic (e.g. to improve self esteem) and extrinsic (e.g. to earn the respect of peers) factors (Sevene et al, 2012). Heazlewood et al. (2016a) compared male and female Sydney WMG masters athletes to evaluate similarities and differences in participant motivation. Genders displayed similarities with factors associated with goal achievement, health orientation and affiliation as most important. Discriminant analysis indicated affiliation and competition as most discriminating with females having higher affiliation scores, whereas males displayed higher competition scores (Heazlewood et al., 2016a). Heazlewood et al. (2016b) examined machine learning procedures for predicting gender from psychological data collected based on motivations to compete at the Sydney WMG. It was demonstrated that using MOMS data, gender for Sydney WMG athletes could be predicted with accuracy of 64.4% (Heazlewood et al., 2016b) using

a multiplayer perceptron neural network (Fausett, 1994). Walsh, heazlewood, Climstein (2018) slightly increased this accuracy using gradient boosted decision trees (Friedman, 2001; Friedman 2002). If significant lift in accuracy was obtained, perhaps this could be used to provide a better understanding of the relationship between motivation to compete in masters sport and gender.

Discussion

A record of demographical data, including several indices of health (smoking, drinking, incidence of chronic disease/disorder, surgical procedure, Rx'd medication, injury history) was successfully collected for a large representative sample of athletes who participated in the 2009 Sydney WMG. This data will help allow an understanding of significant factors affecting this unique cohort as well as potential health implications for long-term exercise adherence as recommended by health professionals.

More detailed analysis (as reported in the literature) demonstrated WMG athletes demonstrated significant improvements in various health related indices over other populations as control groups, including an age matched comparative national population obtained from the Australian Government Australian Bureau of Statistics. Notable among these improvements for masters athletes were body mass index for the majority, but not all participants. Females also had lower BMI than male masters athletes. This evidence of improved classification in one index of health (reduced BMI) for masters athletes (when compared to the general population) implied there are either improved levels of this index of health with aging due to adherence to sport or possibly the reduced BMI is advantageous and contributes to this cohort adhering (or being attracted) to masters sport at older ages.

Smoking prevalence was lower than global (World Health Organisation) and Australian (ABS) comparative data. It was possible that improved lifestyle behaviours might have contributed to improved economic status and health, allowing competition at older ages.

As well as gender based differences, significant differences were also identified when comparing WMG lipid results to the Australian general population (Australian Bureau of Statistics data for adult Australians). WMG athletes demonstrated clinically superior TC (4.47 ±1.11 mmol/L), HDLs (1.75 ±0.79 mmol/L), and LDLs (2.92 ±0.96 mmol/L) when compared to Australian general population parameters (TC: 5.07 mmol/L, HDL: 1.34 mmol/L, LDL: 3.13 mmol/L). This gave increasing evidence of improved health in masters athletes. WMG participants demonstrated improved values in a number of CVD risk factors when compared to the general population with female WMG participants presenting improved scores for CVD risk factors when compared to males. Hence, Sydney WMG masters athletes exhibited evidence of superior health when compared to the general population within Australia.

Then trend of improved health indices was reiterated in the reduced prevalence of chronic disease and disorder indicators reported by the North American participants of the Sydney World Masters Games compared to the US population. This included obesity where, the prevalence of obesity was significantly lower in incidence for North American WMG competitors when compared to Canadian and US populations.

With evidence of improved health indices associated with masters competition, it was logical to investigate factors connected with motivation to compete in masters sport. Socialization with other participants was the most important personal motivation for masters sport participation. Health and fitness were less important motivators than socializing to these masters level participants, but still stronger than competition. Particularly notable was that as body mass index increased, masters athletes were more likely to be motivated by socialisation as opposed

to weight loss. Males and females displayed similarities with factors associated with goal achievement, health orientation and affiliation as most important. Discriminant analysis indicated affiliation and competition as most discriminating with females having higher affiliation scores, whereas males displayed higher competition scores. This information could perhaps be adopted by those promoting sport and physical activity for people at older ages, in order to encourage participation.

There was concern that due to age related changes, increased risk of injury would be associated with highly competitive sport for the aging athlete. Results demonstrated the injury incidence during preparation for the tournament had similarities to, but was in fact shown to be significantly less than for other competitive sporting populations. Some gender and sport based differences in injury location and classification type were identified. It was concluded that the incidence and consequences of injury was not sufficient to warrant a suggestion to not participate due to injury risk. This finding was considered a positive result due to the evidence for health benefits from exercise.

It has been shown by the research on Sydney WMG athletes, that there is evidenced for improved health within this cohort. Additionally there is not an associated increased risk of injury with these aging athletes. Based on this the promotion of such sport events for older athletes is supported, in order to promote potential health benefits with an acceptable risk of injury. Given this conclusion, seeking an improved understanding of the motivations behind masters athletes is justified. It was found there were some differences in motivations between males and females and also socialisation was one of the biggest motivating factors. Socialisation was in fact a greater motivating factor for obese than for non-obese athletes.

Conclusion

Health care professionals encourage physical activity and more specifically exercise adherence as a countermeasure to many chronic diseases and as a mechanism for successful aging. A record of demographical data, including several indices of health (smoking, drinking, incidence of chronic disease/disorder, surgical procedure, Rx'd medication, injury history) was successfully collected for a large representative sample of athletes who participated in the SWMG. The data reported and analyzed during this study suggests that the exercise adherence associated with competitive masters sport may reduce the incidence of many common chronic diseases in masters athletes. The scientific community may draw from these results a deeper understanding of various health related parameters affecting masters athletes as well as others that have demonstrated long-term exercise adherence across the lifespan. This data will allow a detailed understanding of significant factors affecting this unique cohort as well as potential health implications for long-term exercise adherence as recommended by health professionals.

Acknowledgements

Assistance was provided by the SWMG Committee in addition to technology support from Evan Wills from the Australian Catholic University. The assistance of the ABS for allowing access to the Australian National Health Survey 2007–2008 results via a data sharing agreement, was appreciated. Special thanks to the more than eight thousand masters athletes who took the time to participate in this project and contribute to the research on this unique cohort of athletes.

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Cite this article as: Walsh, J., Heazlewood, I.T., DeBeliso, M., Climstein, M. (2018). A Profile of Sydney World Masters Games Athletes: Health, Injury and Psychological Indices. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 37–52. DOI: 10.18276/cej.2018.3-04.

FORMS OF ACTIVITIES WITH A DOG AS MODERN TYPES OF PHYSICAL RECREATION

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Abstract The rapid civilisational development that took place in the second half of the 20th century, and the resulting changes in the conditions and ways of people's lives brought forth a number of social phenomena, both positive and negative. Physical activities, i.e. any forms of physical effort undertaken voluntarily in leisure time for entertainment and health purposes, contribute greatly to overcoming the dangers of modern civilization. Among these, activities with the participation of a dog are becoming increasingly popular. These activities are exercised by people of all ages in the form of dog sports, as well as for recreational and therapeutic purposes.

The aim of the paper is to present various forms of activities with a dog as modern types of physical recreation exercised by people of all ages.

Regular exercise with a dog greatly improves the well-being and provides a feeling of harmony and inner peace. It is becoming yet another modern form of activity.

Key words physical activity, agility, type 1 diabetes, dog sports

Introduction

Various specialists consider exercise to be one of the pre-requisites of maintaining or improving one's health (Jaskólski, 2002; Skarżyński, 2003).

The effects of physical activity on the human body are not limited to the physical aspects. "There is also an entire range of psychological and, more precisely, psychosocial outcomes" (Sas-Nowosielski, 2003, p. 22). Specialists view physical activity as a form of therapy for specific mental and emotional disorders. Moreover, regular physical exercise contributes to alleviating anxiety and depressive mood, and enables the development of self-esteem (Sas-Nowosielski, 2003).

Nowadays, work takes up major part of the day, and its conditions, employers' demands and stress levels are increasing. Fast pace of living, higher workload, continuous necessity to make choices, desire of pursuing one's career are a few of the many factors that impact our mental health and cause mental fatigue.

Prolonged nervous stain and excessive amount of overlapping stressors adversely affect human health, and may result in mental fatigue, nervous breakdown, or even depression. The lifestyle of continuous rush makes it necessary to look for forms of recreation that make it possible to relax and relieve some of the increasing nervous tension. With a view to mental health, it is very important to use leisure time skillfully (Cynarski, 2017). The great popularity of the dog as a pet animal has recently resulted in the establishment of a number of new sports with the participation of dogs (Jastrzębska, Gugołek, Strychalski, 2017). This type of physical activity of a person with a dog may be of sport, recreational, or therapeutic nature.

Conducting therapeutic classes with the participation of a dog is a very complex issue. Due to its extensiveness and diversity of forms of dogotherapy, it will be described in a separate article. This work aims to show the types of cynological sports that have been created. Certainly their diversity contributes to the increase in the number of people undertaking such physical activity. At the present moment, it is not possible to estimate the number of people practicing kennel sports. They are taken by people who repeatedly create informal clubs for dog lovers and do not have to be members of canine associations. Hence, the lack of reliable data on the number of people taking forms of activity with the dog.

Common forms of physical activity involving dogs

From the very beginning, when a man domesticated a dog, the dog was to serve a man. Initially, they were so-called guardians of the herd. Over the years, dogs of dog breeds arose due to their usefulness. Considering the cynological sports, depending on the discipline, dogs are also picked up in terms of races, predispositions (Journal, 2013; Buss, 2001).

Today, in Poland and all over the world, there are many activities involving dogs. The most popular ones include: agility, obedience, flyball, tracking, dogtrekking, sheep herding.

Obedience

Obedience as a dog sport involves training a dog in a so-called basic obedience. At the right time and upon a cue, the dog should follow the given commands. This discipline originated from the training of police and military dogs, and the German Shepherd was one of the first breeds to receive such a training. Over time, obedience evolved into a dog sport, with its own rules, regulations, and competitions at various levels of difficulty. In Poland, both pure breed and non-breed dogs may participate in obedience competitions and tests. To be admitted to a competition, a dog must have its start sheet and must be of sound health. Obedience competitions of the following classes are held in Poland:

- Class 0 – for beginners,
- Class 1 – for advanced participants,
- Class 2 – for advanced participants,
- Class 3 – for advanced participants; international rules established by FCI apply.

A competition is supervised by a commissioner, secretary and a competition supervisor (http://www.szkolenie.lodz.zkwp.pl/praca-psa-pasterskiego).

Obedience as a dog sport is particularly popular among dog lovers and dog owners. It does not involve huge costs, nor requires specialised equipment. It does require, however, regular physical exercise with the dog. This activity involves systematic training, but also daily walking and working with the dog. It has a positive impact on the mental health and allows a person to relax after a hard day's work.

Rally-o is a more popular, recreational form of obedience. This form has its own rules, less stringent than the original discipline.

Nowadays many training methods are used. Each of them is designed to best train your dog. Currently, this discipline as well as other disciplines put a great emphasis on the use of training methods based on the rewarding of a dog. The use of aversive methods and electric collars mostly leads to increased aggression in a dog or so-called learned helplessness. This, of course, disrupts the relationship between the dog and the guide (Salomon, Wynne, 1953; Schilder, Van der Borg, 2004).

Herding

Herding is another form of activity with a dog. This discipline originates from the use of utility dogs that helped farmers in their work. It involves the cooperation between a man and a dog with mutual understanding and trust. Shepherd dogs of various kinds are used in herding all over the world, but most it involves Border Collie, a breed best suited for this task. This activity has its origins in England. Dog trial is a herding competition held all over the world. It is particularly popular in the British Isles, where it is regarded to be almost a national sport. In Poland, herding is still a developing discipline, but one that keeps attracting more and more fans. This form of physical activity involves great commitment of the guide and immense emotions. This sport requires exceptional consistency and great effort by both a man and a dog (http://www.szkolenie.lodz.zkwp.pl/praca-psa-pasterskiego).

Flyball

Flyball is a much less popular sport. It involves racing of dog teams against each other. Each dog has to run through four hurdles to a box that, when pressed with a paw (or the entire body for small and lightweight dogs), ejects a ball to be caught by the dog, who then returns to the owner as fast as possible. Flyball is run in teams of four dogs. It was created following and idea of a Californian Herbert Wagner, who invented a tennis ball thrower in the 1970s (https://pl.wikipedia.org/wiki/Flyball).

Regrettably, this sport is a frequent cause of dog injuries, and does not require handlers to make physical effort. It is a very rare form of activity in Poland.

Dogfrisbee

Disc dog is a discipline that requires a lot of physical activity, precision and good coordination of movement of the handler. The sport involves a man throwing frisbee to be caught by a dog. The handler demonstrates various techniques of throwing, and the dog catches the disk by various methods. There are two categories of this sport: long distance, which requires a disc to be thrown as far as possible to be caught by the dog before it falls onto the ground, and freestyle involving a combination of various disc throws, often accompanied with gymnastic exercises and catching the disc by the dog by various techniques. Today, national and international disc dog competitions are held.

Dogtrekking

Dogtrekking is another sport involving cross country running with dogs. There are various distances to be made as fast as possible, following the respective checkpoints. The most popular distances are 10–15 and 20–25 km. They can be, however, freely set for the purposes of a competition. The first to pass all the checkpoints is the winner. This sport can be exercises by entire families and dogs of all breeds.

Dog agility

Agility can be exercised as a sport, recreational activity, or a supportive treatment method for children and adults. It involves directing a dog to complete series of obstacles. Agility was developed in the 1970s, and was originally intended to be an interlude during dog shows. The first public demonstration of dog agility was held at the most famous Cruft's Dog Show in 1978. It instantly turned out to be enormously popular. Within a short time the British Kennel Club established dog agility rules. The World Canine Organization (Fédération Cynologique Internationale – FCI) adopted the dog agility rules and since 1991 considers it to be a sport. (www.zkwp-szkolenie.pl/dyscypliny/agility/agility_regulaminy).

Agility was modelled on equestrian competitions. The sizes and types of obstacles were made different over time, which made this sport very spectacular.

Each participant of a competition starts in three events: agility open, jumping open, and the so-called tests (A0, A1, A2, A3). Flawless completion of a class at three different competitions promotes the participant to the next class. The final classification includes the combined results of the agility open and jumping. A disqualification at any of these excludes the participant from the competition. An agility course and a jumping course differ in terms of the use of obstacles. Agility combines nimbleness and speed. If the time result is the same, the couple (dog + handler) who made fewer mistakes in completing the course is the winner. Agility as a dog sport is also practiced at a competitive level as a national cup and championship, as well as world championship. Today, it is also developed as a form of recreation for children, young people and adults.

Agility requires a systematic approach that promotes physical fitness. The intensity of agility trainings depends mostly on two factors: age and physical fitness of a person and the age and psychophysical capabilities of a dog. Some dog breeds are particularly suitable for agility. These breeds should be characterised by exceptional energy and willingness to cooperate with people. They mostly include FCI group I breeds. Border Collie and Pyrenean Shepherd are particularly suitable. The owners of these breeds dedicate much more time and effort to their daily trainings than the owners of other breeds, which translates into much better results at sports competitions. Breeds with milder temperament also take part in dog agility, and are mostly preferred by older people with diminished physical fitness and constitution. The latter, however, is no obstacle in participating in dog agility trainings and competitions. Today dog agility events are organised at a regional level for those who treat it as a form of recreation, and also on an international level, e.g. as World Championships where the best dog agility contestants of various countries compete against each other. Dog training in the direction of agility changes its thinking and has a positive effect on the way the dog communicates with the guide (Marshall-Pescini, Paddalacqua, Barnard, Valsecchi, Prato-Previde, 2009;Ekman, Davidson, 2004; Cantazaro, 2003).

Agility is not only physical exercise, but also a means of developing an immense bond with the dog, and sharing extraordinary emotions. Taking advantage of this particular aspect of this activity, in Szczecin agility was suggested as a supportive treatment for children with type 1 diabetes as a means of increasing insulin sensitivity.

Agility events were adapted to the abilities of children with type 1 diabetes (Otto-Buczkowska, Jarosz- Chobot, 2001; Ponikowska, Adamczyk, 2006). The training cycle resulted in lowering the level of HbA1c glycated haemoglobin, and reduced daily doses of insulin. The contact with a dog also positively influenced the psyche of a child, increased his confidence and was a source of many positive emotions (Niewiadomska, Radzijewska, 2008; Niewiadomska, Radzijewska, Horodnica-Józwa, Petriczko, 2010).

Another example of taking advantage of a contact with a dog as a form of therapy is the implementation of a project in 2016 at a Penal Institution in Goleniów aimed at helping prisoners in rehabilitation. The project was founded by a former employee of the Penal Institution, Mr. Tomasz Wojciechowski, and an employee of the Goleniów Society for Animal Care – Mrs. Ewelina Pietrzak-Giec. Dogs from the Goleniów Society for Animal Care were assigned to selected inmates, who were asked to take care of the dogs for 6 weeks. Apart from basic dog care, i.e. feeding, cleaning, and walking, the inmates learned about various forms of activity with a dog and dog sports, including agility. The inmates managed to establish a bond with the dog, expressed empathy towards it, and commitment in the care. After the end of the project, many inmates kept asking about the dogs.

Summary

Forms of activity with a dog include sport, recreation, or therapy. Regardless of the form of classes, the key element in running a dog is the proper selection of training methods. The best training effects can be obtained by rewarding the dog. The use of aversive methods, punishments does not bring the desired results and may lead to aggression (Blackwell, Twells, Seawright, Casey, 2008).

Regular exercise with a dog greatly improves well-being, provides a feeling of harmony and inner peace, and can constitute a way of coping with stress. Taking advantage of such forms of activity with a dog may be one of today's types of recreations that is a source of both satisfaction and pleasure.

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Cite this article as: Niewiadomska, M. (2018). Forms of Activities with a Dog as Modern Types of Physical Recreation. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 53–58. DOI: 10.18276/cej.2018.3-05.

SPECIAL ENDURANCE OF YOUNG GYMNASTS: THE ROLE OF AEROBIC CAPACITY IN FATIGUE DEVELOPMENT IN THE TRAINING

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Abstract In artistic gymnastic alteration of all component of coordination capacities may related to fatigue. So the resistance to fatigue is a specific endurance component, which has direct relation to the techniques of gymnastic exercises. We supposed that changes of motor actions precise in the process of fatigue development during training sessions might presumably have a negative impact on the quality of performing complex gymnastic elements and combinations and set the goal to determine the significance level of aerobic capacity for special endurance. Twelve young skilled gymnasts aged 15–18 years measured the maximum oxygen consumption (VO_2max). During the training sessions specially designed tests of specific endurance were carried out, heart rate (HR) was measured and the quality of the presentation of the combinations was evaluated (by the sum of the judges' ratings of all the elements). The interrelation between VO_2max, HR in progress of gymnastic combinations and the quality of their performance were analyzed. Results showed that a higher aerobic capacity contributes to a relatively lower HR when performing intense gymnastic combinations and a slower development. Iof "coordination fatigue" t may be of special importance for young athletes at the stage of advanced specialization when a great volume of complex combinations is learned and thus, high volume of training loads is performed. According to obtained data use of the proposed endurance tests is of great importance for control of maintenance of aerobic capacities by young athletes. Account of the factors of "coordination fatigue" development, related to aerobic capacities, may be of special importance for young gymnasts at the stage of advanced specialization when a great volume of complex combinations is learned and thus, high volume of training loads is performed.

Key words gymnastic training, specific fatigue, aerobic capacities

Introduction

Special endurance is an indispensable part of the process of forming and improving the championship of athletes of all specializations. In recent times considerable success has been achieved in understanding the essence of specific endurance, as a basis for sport-technical excellence and the individual components of stress in sport (Mac Dougall, Wenger, Green, 1991). It should be emphasized that it is particularly complex to place special endurance in the various sports. This involves primarily disciplines that consist of many competitions which need different characteristics in their movement structure and require maintaining high motor coordination regardless of fatigue (Astrand, Rodahl, 1977). These include gymnastics. It was noted that when performing full sets of gymnastic movements in competitions of a gymnastic all-round event, there was very high heart rate (HR) (Smolevsky, Gaverdovsky, 1999; Zasada, Sawczyn, Mishchenko, 2006). As it is commonly believed, after all the exercises, HR is often approximated to the heart rate of athletes practicing endurance disciplines. Therefore, many gymnastics theorists suggest that HR changes may be one of the measures of exercise load in sports gymnastics and one of the indicators of physical fitness (Arkayev, Suchilin, 1997; Sawczyn, 2000). It is well known that high physical fitness allows for a better tolerance of effort of varying intensity. Although the physical fitness may be the ability to perform a specific work in a unit of time, and thus the ability to release maximum power, the most common indicator is the maximum oxygen uptake (VO_2max). In most cases, there is a very high correlation between the ability to achieve outstanding results in endurance disciplines and the VO_2max individual value. In the case of gymnasts, aerobic capacity (as measured by VO_2max per kg of body mass) should be considered very different (Mac Dougall, Wenger, Green, 1991; Nybo, Rasmussen, 2007).

Significant and constantly increasing the difficulty of exercise in modern gymnastics causes numerous complications in proper planning of training loads and selection of the appropriate training measures. In order to shape a high technical level and the special endurance of gymnasts, there should be provided a broad and comprehensive basis for the implementation of a variety of structurally different exercises for each of the competitions. First of all, the endurance in gymnastics should include the observance of certain conditions conducive to the improvement of coordination capacities in technical preparation (Gaverdovsky, 2003; Sawczyn, Zasada, Mishchenko, 2005). High aerobic capacity allows for better tolerance of effort of different intensity (Astrand, Rodahl,1977). Although the ability to perform specific work in a unit of time, and thus the ability to improve better (Astrand, Rodahl, 1977; Loren, Chiu, 2003; Mac Dougall, Wenger, Green,1991), as well as VO_2max may be the physical fitness measure. Such a demanding programme, which the gymnast has to master at the right time, puts the athlete's ability in the training process and training endurance to the forefront (Smolevsky, Gaverdovsky, 1999; Sawczyn, 2000). At the same time, sports activities should not be conducted at the limit of exercise capacity, in order to obtain the highest level of technique, even if the gymnast has mastered it to a very good degree. As a consequence, in the process of training, there appears the need to "create" a specific "surplus" (reserves) of energy potential for proper training and startup activities (Arkajew, Suczilin, 2004; Zasada, Sawczyn, Mishchenko, 2006). In securing specific preparation for the realization of motor skills in the technical elements of different movement patterns, there are certain limitations, which are determined by insufficient examination of these issues. At present, it is limited by the number of endurance-shaping agents used within its influence on the techniques of making various elements and gymnastic exercises.

Therefore, in sport gymnastics, the time during which fatigue occurs during training has a significant influence on the quality of performed motor tasks. In other words, the aerobic power (VO_2max) remains to have the influence on the performance of the qualities of the workload. It is assumed that the achievement of the effective training process and shaping the technique of exercising gymnastics is possible under the condition of achieving a high degree of special endurance. An important component of such endurance is the aerobic capacity of gymnasts. The purpose of the study was to clarify the effect of aerobic capacity on the exercise intensity in the case of exercising full gymnastic combinations. The study examines also how this affects the quality of performing complex gymnastic elements and combinations during a training unit.

Material and methods

Participants. Twelve gymnasts from the age of 15 to 18 years (juniors in the first level of the sport class) who attained significant sports performance in the national gymnastics and presented training at a similar level of technical training took part in the series of research. Prior to the study, all the gymnasts' height (in cm, with the accuracy of 1.5 mm) and weight (in kg, with the accuracy of 0.1 kg) were determined. The participants were measured wearing lightweight clothing and no shoes. The percentage of body fat was estimated with Tanita BC-418MA devise.

The anthropometric characteristics of the participants are presented in Table 1.

Table 1. Anthropometric characteristics of young gymnasts

Indicators	Age (years)	Body height (cm)	Body mass (kg)	BMI (kg/m2)	Fat (%)	Fat Mass (kg)	Lean Body Mass (kg)
Mean	16.1	168.0	61.0	21.6	10.9	6.7	54.3
Min	15.1	162.0	52.4	19.2	5.9	3.6	48.8
Max	18.0	176.0	73.0	23.6	15.4	9.7	63.4
SD	0.4	1.5	1.1	0.3	0.5	0.2	0.9

Training content. In order to determine the intensity of the workload of the examined gymnasts, researchers used the method of S. Sawczyn (2000). The calculation formula assumes that the intensity of the work of the athletes depends not only on the overall number of the performed elements, but also on the difficulty of the exercises specified in the regulations of the International Federation of Gymnastics. In the formula, the sum of the elements of successive difficulty groups was multiplied by a corresponding increasing coefficient:

$$I = (\Sigma EA + \Sigma 2EB + \Sigma 3EC + \Sigma 4ED + \Sigma 5EE + ...)/(T + P),$$

where: I – intensity index; T – total duration of the training (in mins); P – number of approaches; ΣEA(B, C, D) – sum of elements in particular groups of difficulty.

The characteristics of intensity of the tested group of gymnasts are presented in Table 2.

Table 2. Characteristics of daytime training loads of trained gymnasts

Indicators	Volume (number of elements)			Intensity (intensity index)			Complexity (number of elements)					
							1			2		
	M	Ś	D	M	Ś	D	M	Ś	D	M	Ś	D
Mean	318	407	482	1.69	2.20	2.95	131	163.0	194	56	108	195
Min	300	380	450	1.51	2.02	2.51	120	150.0	180	40	80	140
Max	380	450	550	2.02	2.51	3.53	150	180.0	220	80	140	250
SD	24	31	37	0.11	0.19	0.22	9	13.3	17	7	10	18

M – small, Ś – medium, D – large) with programming of training volume (number of elements), intensity (number of elements in min) and coefficient of effectiveness – complexity (1 – difficulty groups in according with FIG classification: C, D, E, F not in combinations, 2 – number of elements of higher difficulty groups in according with FIG classification: C, D, E, F in combinations.

The data presented reflect such numerical values as: values of the elements, the intensity and the complexity (the quality) of the exercises, which are characteristic for prospective gymnasts.

Procedure and endurance tests. Before the single training unit, after the gymnasts did the standard warm-up and after their completion of the unit, there was performed a test of their special endurance. Endurance tests looked as the standard practice for strictly defined motor tasks – gymnastic circuits and combinations in floor exercises and pommel horse exercises. The intensity of the test exercises was the model of the most stressful situations that happen in the training of highly qualified gymnasts. The test consisted of two parts: floor exercises and pommel horse exercises. Tests of floor exercises and pommel horse exercises were performed on different days. Each of them in one training session was carried out twice. To assess the effect of accumulation of fatigue in the training process, tests were conducted at the beginning and at the end of a typical for a high performance gymnast's microcycle. The content of the special endurance tests of the gymnasts is shown below.

Special endurance test – in floor exercise (1)

The test consisted of basic back and forward acrobatic jumps, separated by power and flexibility elements, which were to be made in a strictly defined order according to the order of their occurrence during sports competitions. This test consisted of six tasks: 1. Acrobatic backward combination: cartwheel with 1/4 turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand. (Structure III FiG); 2. Acrobatic forward combination: forward handspring and tucked salto forward to stand. (Structure II of FiG); Acrobatics backward combination: cartwheel with 1/4 turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand; 4. non-acrobatic elements: keep side split and press to handstand with straight arms and bent body (keep 2 s). With handstand 1/2 turn and return to the starting position. (Structure I FiG); 5. Acrobatic forward recombination: handspring forward and tucked salto forward; 6. Acrobatic backward recombination: cartwheel with ¼ turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand. The proposed set of six movement tasks, repeated twice in identical order of the connections with a break of 60 s (in total: 12 exercises), consist a complete test when it comes to floor exercise. The time of performance was 70 (±6) s.

Special endurance test – in pommel horse exercises (2)

Starting position – the side support frontways. The test consisted of four successive tasks: 1. Jump with double legs to the side support frontways and smoothly make the double legs four circles to the left (or right); 2. Smoothly move to the side support rearways and cut left leg back to the straddled support, then cut right leg back

into the support frontways and cut left leg forward to the straddled support; 3. Without motion loss, scissors forward to the right and scissors forward to the left and cut the right leg forward to the side support rearways; 4. Without losing the rhythm, make the double legs four circles to the left. A full test consists of a two-time repetition of 4 tasks without stopping or a loss, with 60 seconds of rest. The test took over 40 ±5 s. These two types of gymnastic exercises were chosen to develop the test complex because they are the most difficult in terms of requirements for endurance and resistance to fatigue.

Before the endurance test, its reliability was confirmed on the basis of the results obtained from the same athletes in two series of tests conducted at intervals of three weeks. Correlation coefficients of HR (r = 0.89) and time (r = 0.87) were measured.

Measurement methods. Under laboratory conditions, a direct measurement of maximal oxygen uptake (VO_2max) was performed. The subjects refrained from intensive exercise during the previous 24 hours (rest day). The gymnasts were instructed to take a carbohydrate rich diet the days before the exercise tests. Before the start of the test, a warm-up of 5 min on ergometer (70–100 w) was performed. All measurements took place under the same conditions of temperatures (20–23°C) and humidity (45–55%). Before the trials, the athletes were familiarized the test procedures. The stepwise tests used a "refuse" test on a bicycle ergometer with the person in a sitting position with increasing load. The initial load was 1.5 $W \cdot kg^{-1}$ body mass at a rate of 50 rpm. After 5 minutes of effort, 0.25 in every 1 min of effort have increased the load. There has been used Jaeger's EOS Sprint measuring tool and a bicycle ergometer connected to a computer. During these test, the following parameters were observed for respiratory and circulatory functions: oxygen consumption ($VO_{2)}$ and carbon dioxide production ($VCO_{2)}$, respiratory gas-exchange relation (RQ), lung ventilation (V_E), breath frequency and tidal volume (V_T). Heart rate (HR) was monitored by electrocardiogram (Sport-tester Polar PE 3000) in all special endurance tests using the standard procedure for applying electrodes. The heart rate was recorded continuously by the Sport-Tester in 5 s stationary average. Before the trials, the athletes were familiarized the test procedures. The average value during the execution of each test of special endurance was calculated. The maximum HR was determined as the largest HR by for 5 seconds in the final part of the stepwise load after reaching VO_2max.

In the training units, the floor exercise and pommel horse exercises tests were performed in two successive micro-cycles. In the first series the floor exercise tests and in the other of the pommel horse tests were performed. Three competent certified judges, in accordance with FiG's refereeing rules, judged the reduction of scores (errors) of the performed exercises. The average value of the estimates from the assessments of each of the judges (experts) was used. Heart rate was also recorded during the execution of tests.

Statistical analysis. The obtained test material was subjected to mathematical and statistical analysis – with the use of program "Statistic 5.0 PL" in the "Excel 97". One of the directions of the analysis was evaluation of using the test of the gymnasts' special endurance for assessing the degree of gymnastics-specific fatigue, which affects the quality of performing gymnastic exercises. To do this, we compared the results of measurements obtained from the same gymnasts in the two series of tests in order to assess the significances of exercise heart rate and the performance of exercise (reduction of scores) differences between successive measurements at start and end of the training unit. Differences in the value were examined by Student's t test. Prior to all analyses, normality of the data was assessed by the one-sample Kolmogorov–Smirnov test. Values were presented by means ± standard deviations, and statistical significance was set at $p < 0.05$.

In order to assess the relationship between the aerobic power results and the quality of the performed motor tasks, the Spearman rank correlation was used. This correlation is used when one of the qualities is measurable and the other is descriptive or when the values of the qualitative characteristics are approximates (judges' scores). Determining the intensity of the correlation based on the magnitude of the coefficient "r" was made at significance, * $p \leq 0.05$ and ** $p \leq 0.01$.

Results

The characteristics of the aerobic capacities of the examined athletes were at the levels that are typical for moderately trained healthy individuals. The levels of maximum oxygen uptake and pulmonary ventilation corresponded to those typical for gymnasts of high qualification. At the same time, there were individual differences. The characteristics of aerobic capacities shown in Table 3 indicate that there is a significant variation in the basic indicators of the peak potential of the oxygen delivery system.

Table 3. Characteristics of the gymnasts' aerobic capacities during aerobic test on the bicycle ergometer

Indicators	VO_2max ($l \cdot min^{-1}$)	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	V_Emax ($l \cdot min^{-1}$)	V_Tmax (l)	HRmax ($beat \cdot min^{-1}$)
Mean	2.86	46.87	110.0	2.34	193.0
Min	2.53	40.81	82.6	1.79	181.2
Max	3.08	54.02	135.5	2.95	201.5
SD	0.25	2.70	9.2	0.34	3.1

The variability of VO_2max (per kg of the body mass) and maximum lung ventilation during exercise (V_Emax) in 3 of the best and worst performing gymnasts were 20.5 and 22.3%, respectively, with high HRmax similarity.

Evaluation of exercise intensity during training sessions based on the HR response of two standard systems at the beginning and at the end of the training unit on the sixth day of the microcycle (Table 4) shows a high level of intensity (approximately 80% HRmax). One may notice an increase of this response at the end of the training unit. This is the place both in floor exercises, and on pommel horse exercises.

Table 4. Heart rate response (beat per min, mean) of the gymnasts during two endurance tests: floor exercises and two pommel horse exercises (in bracket) in a single training unit

Indicators	Start of the training unit		End of the training unit	
	HR mean, max and min			
	Test 1	Test 2	Test 3	Test 4
Mean	148 (151)	151 (155)	151 (153)	157 (158)
Min	140 (144)	140 (146)	144 (144)	147 (147)
Max	153 (161)	160 (164)	158 (162)	163 (173)
SD	4.01 (5,28)	6.76 (5.89)	4.69 (6.11)	4.12 (7.93)

Significant differences at $p \leq 0.05$: 1–4.

According to the tables, the HR response of gymnasts on the pommel horse was individually varied to a greater extent (by maximal values) than the reaction of those doing floor exercise. This was evident when fatigue was accumulated at the end of the training unit.

The analysis of the relative intensity of exercise (by HR) during typical exercise (endurance tests**)** with aerobic capacity **(**VO_2max per kg of body mass) against fatigue accumulation at the end of the training unit showed a significant correlation (negative correlation). A similar relationship was observed in both floor and pommel horse exercises. The correlation strength increased with the second test (Table 5).

Table 5. The relationship between VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) and HR mean in two endurance exercises on floor exercise and pommel horse exercise performed at the end of workout training unit (the beginning and the end of the microcycle)

Types of exercises	Special endurance test	Correlation between VO_2max and HR mean of tests	
		the beginning of the microcycle	the end of the microcycle
Floor exercises	Test 1	–0.63*	–0.96**
	Test 2	–0.85**	–0.95**
Pommel horse	Test 1	–0.78**	–0.97**
	Test 2	–0.82**	–0.96**

Significant differences at *$p \leq 0.05$; **: $p \leq 0.01$.

The strength of the correlation was also increasing from the beginning to the end of the microcycle.

Due to the higher predicted effect of increased exercise intensity (percent HR vs HRmax) on the development of fatigue and motor coordination, there has been examined also changes in the performance of the exercise (reduction of assessment points) during the pommel horse endurance test at the beginning and at the end of the training unit (Table 6).

Table 6. Changes in the performance of exercise (reduction of scores) during endurance test on the pommel horse at the beginning and at the end of the training unit

Indicators	At the beginning of the training unit		At the end of the training unit	
	reduction of scores (errors)			
	Test 1	Test 2	Test 3	Test 4
Mean	1.44	2.72	1.86	3.25
Min	1.10	1.50	1.30	1.60
Max	1.80	3.60	2.60	4.30
SD	0.22	0.68	0.40	1.00

Significant differences at $p \leq 0.05$: 1–2, 3–4, 2–4; when $p \leq 0.01$: 1–4.

In the fourth endurance test (performed after one minute of rest after the third test), there has been observed the deepest drop in exercise precision, which confirms the magnitude of the errors. The quality of gymnastic exercises (reduction of scores) was evaluated in both special endurance tests performed on pommel horse and in floor exercise. The results of the measurements were similar. Therefore, only one of them is given. The results of the

measurements of both tests were used for the subsequent analysis. The quality of exercise in the trials (reduction of scores) depended on the relative intensity of exercise (HR average) during exercise (Table 7).

Table 7. The correlation between average HR and quality of gymnastic exercises performed on pommel horse and of floor exercise (in brackets), with measured amount of errors (score reduction) during a training unit

Tests	At the beginning of the training unit		End of the training unit	
	HR mean			
	Test 1	Test 2	Test 3	Test 4
Test 1	0.30 (0.74**)	–	–	–
Test 2	–	0.74**(0.76**)	–	–
Test 3	–	–	0.76**(0.61*)	–
Test 4	–	–	–	0.79**(0.76**)

Significant differences at: * $p \leq 0.05$; ** $p \leq 0.01$.

As shown in Table 7, significant correlations (positive correlation) were found between the mean HR and the quality of exercise performed during the second, third and fourth endurance tests. These data show the increase in intensity of work from the beginning to the end of the training unit (average HR increase) and the increase in the number of exercise errors which is dependent on the HR increase.

The average heart rate of gymnasts in rehearsal tests (on fatigue) of the standard test on pommel horse and in floor exercise in training units depended on $VO_{2\ max}$ per kg of body mass (Table 8). The relationship between these oxygen performance characteristics was high (negative correlation) at the beginning and at the end (in brackets) of the microcycle.

Table 8. The relationship between VO_2max and HR mean in endurance gymnastic tests (floor and pommel horse exercises) at the end of the training unit, done at the beginning and at the end of the microcycle (in brackets)

Type of exercises	Strength test	Correlation between VO_2max and HR mean tests (r)
Floor exercises	Test 1	–0.63*(–0.90**)
	Test 2	–0.85**(–0.92**)
Pommel horse exercises	Test 1	–0.71*(–0.91**)
	Test 2	–0.82**(–0.93**)

Significant differences at *$p \leq 0.05$, **: $p \leq 0.01$.

In the fifth training unit (at the end of the microcycle), the correlations were higher than at the beginning and clearly, during two tests, they occurred at the beginning of the training unit.

The endurance tests on a pommel horse during a medium-loaded training unit indicate a high degree of variation in the quality of performed motor tasks (with the number of errors made increasing) against the increasing fatigue (Table 9).

Table 9. The characteristics of gymnastic exercise quality changes (differences of errors in points and percentages – in brackets) in four consecutive exercises (tests) performed on the pommel horse during a single training unit

Indicators	Differences of errors in points and percentages			
	2–1	4–3	3–1	4–1
Mean	0.95 (79)	1.09 (75)	0.24 (16)	1.33 (110)
Min	0.30 (150)	0.40 (130)	0.10 (67)	0.50 (222)
Max	2.40 (25)	1.60 (33)	0.60 (24)	2.00 (42)
SD	0.32	0.18	0.04	0.29

Such changes in the quality of work performed were already present in the first two tests, with a significant increase from 1 to 4 tests.

The final analysis of the aerobic power of the gymnasts for the quality of the special work performed in endurance tests indicates a high correlation of VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) with the degree of point's reduction (increasing number of errors) in training units (Table 10).

Table 10. The correlation between VO_{2max} and special performance characteristics (difference of errors in technical performance between individual tests in points and % – in brackets) during the pommel horse exercises in training units

Tests	Correlation VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) with the difference of errors in technical performance
2–1	–0.87 (–0.89)**
4–3	–0.89 (–0.72)**
3–1	–0.75 (–0.49)**
4–1	–0.91 (–0.89)**

Significant differences at **: $p \leq 0.01$.

The VO_2max correlation analysis was performed taking into account the variations in errors between the four endurance tests during the training unit. The first and the second test were conducted at the beginning and the third and fourth at the end of the training unit. Such an analysis demonstrates that high correlation during pommel horse exercises occurs in all cases, although the largest correlation was between the first and fourth test and the VO_2max of the tested gymnasts.

Discussion

Given the varied nature of individual gymnastics competitions that require the gymnasts to undergo comprehensive physical and technical training, indicators that reflect the magnitude of adaptive responses are of particular importance. Such an integral feature is the energy potential (Astrand, Rodahl, 1977). The fact is that gymnastic exercises are protected, in large part, by anaerobic energy sources. Nevertheless, the overall performance is geared towards evaluating the aerobic capacity of the energy supply system (Mac Dougall, Wenger, Green, 1991). It is known that high aerobic capacity allows for better tolerance of effort of different intensity. It can be assumed that in gymnastics, the time during which fatigue occurs (while training) has a significant influence on the quality of performed tasks. Although the measure of efficiency may be the ability to perform specific work in a unit

of time, and thus the ability to release maximum power, the most common indicator of efficiency is the maximum oxygen consumption (VO_2max). When analyzing the results of the study, we can observe the differences in body mass and height of the examined gymnasts. BMI had no significant impact on the quality of exercise performed by the tested gymnasts, but was associated with VO_2max in ml·kg^{-1}·min^{-1} ($r = -0.49$; $p < 0.05$).

It is known that a gymnast taking part in an all-round event must master at least 52 elements of very high difficulty and complexity. Making exercises such difficult cause numerous complications in performing high workloads (Arkayev, Suchilin, 1997). The tremendous material that must be mastered by the gymnast at the right time puts forward also the physical efficiency, the basis of which is VO_2max. Such characteristics of efficiency can be very helpful not only in the assessment of special endurance but also in understanding the possibility of carrying out significant training loads in particular phases of long-term training (Astrand, Rodahl, 1977; Sawczyn, 2000; Sawczyn, Zasada, Mishchenko, 2005). For the examined gymnasts, the aerobic capacity (measured by VO_2max per kg of body mass) has significantly varied: from 40.8 to 54.0 ml·kg^{-1}·min^{-1}. According to most of the other studies of VO_2max per kg of body mass of gymnasts, they are at 45–50 ml·kg^{-1}·min^{-1} (Smolevsky, Gaverdovsky, 1999). Previously, the gymnastics was ranked as the sport with one of the lowest VO_2max values. On the other hand, gymnasts of all ages demonstrated significant fluctuations in individual VO_2max levels, ranging from 41 to 63 ml·kg^{-1}·min^{-1} (Barancew,, 1985; Smolevsky, Gaverdovsky,1999; Sawczyn, 2000). According to Mc Dougall et al. (1991), the scale of maximum oxygen consumption among the best gymnasts ranges from 48 up to 74 ml·kg^{-1}·min^{-1}. Sawczyn (2000) presents data on the downward trend of $VO_{2\,max}$ from 55.4 ±4.1 to 47.0 ±6.5 ml·kg^{-1}·min^{-1} in the age range of 10–11 years do 17–22 years. The author notes that the data presented may reflect the natural tendency to decrease VO_2max per kg of body mass as a result of mass gain and lack of aerobic training in gymnastics.

Performance requirements in gymnastic exercises may be characterized by the increased of heart rate. By analyzing the results of the research, it can be seen that the response of the gymnasts to the effort made is a high HR response in all gymnasts. During the fourth endurance test, the HR response was at the highest level – 158 (147–173) beat per min. The standard deviation from the mean in the fourth test was 7.93 and the coefficient of variation was 5%. This means that the fourth test scattering was at the highest level in relation to the previous day's efforts on the microcycle. This may indicate that there is the greatest variation in the level of fatigue in these conditions of the endurance of gymnasts and the associated effect of fatigue on the quality of performing complex gymnastic elements and combinations.

In gymnastics, the scale of the sports championship is the ability to perform exercises in six competitions with precision that is not as high in other sports disciplines. The gymnast has to combine all movement acts with the same precision, as they form a complete combination (system), which is evaluated according to strictly defined rules of referees (Vuillerme, 2001; Gaverdovsky, 2003; Arkajew, Suczilin, 2004). Therefore, the influence of fatigue can be seen first of all in the negative changes of the movements precision (Starosta, 1993; Sawczyn, Zasada, Mishchenko, 2005; Zasada, Sawczyn, Mishchenko, 2006). As a result of the performed gymnastics research, the obtained data show that we can characterize the effect of aerobic capacity on the quality of performed motor tasks. These results indicate that there is a high correlation and a very reliable relationship between the parameters given. The effect of greater aerobic capacity can be attributed to lower cerebral hypoxia and less central fatigue when performing gymnastic combinations (Loren, Chiu, 2003; Nybo, Rasmussen, 2007; Rasmussen et al, 2010).

It was shown that there was a negative correlation between aerobic power (VO_2max) and cardiovascular system response (HR) in performing standard endurance tests. Such dependency increases when fatigue is

accumulated at the end of the training unit and training microcycle. Correlations in the last training unit of the training microcycle were even higher and were already present at the start of the training unit in the two tests. A clear increase in fatigue and an HR increase in HR max when performing standard gymnastic exercises at the end of the microcycle is typical for high-level gymnasts (Arkayev, Suchilin, 2004).

This means that even the most intense gymnastic loads of athletes with higher aerobic capacities are relatively less stressful than those with lower $VO_{2\ max}$. This presumably creates the conditions for a slower development of fatigue and for maintaining the quality of performing gymnastic combinations. In modern sports training technology, it is extremely important to seek out and use different methods to evaluate the functional capabilities of gymnasts that could increase the effectiveness of the training process. Developed endurance tests in floor and pommel horse exercises, according to HR and energy expenditure, simulate the most intense conditions of gymnastic combinations and can be a tool for the control of special endurance of gymnasts. This confirms that the method of assessing physiological load according to HR response is effective in managing training loads (Arkayev, Suchilin, 1997; Smolevsky, Gaverdovsky, 1999).

Based on the endurance tests, a number of results indicate a number of fatigue changes in the gymnasts' bodies and their impact on the quality of work done during strictly defined motor tasks, and also their association with aerobic capacity of gymnasts. During the four endurance tests carried out in high load training units, the quality of the work performed by the gymnasts was shown by the size of the errors (reduction of points). The demonstrated dependence was greater on pommel horse exercises, which may be indicative of the highest specific endurance requirements for these exercises. Manifestation of coordination stability includes the other indices of movements control as well (Enoka, Duchateau, 2008; Amann, 2011). They are integrated by fatigue impacts on the function of sensorimotor cortex, which is the highest level of voluntary motions in precise evaluation of time, motion amplitude and value of efforts in athletes. Utilization of endurance tests for evaluation of changes (stability) in coordination capacities ("coordination endurance") under the influence of fatigue is justified by the fact that mechanisms of motion control are complex and under the influence of factors of the same type as well as during various body states change unequally. There exists a positive transfer of ability to maintain stability of these or those characteristics of motor actions in similar according to main biomechanical characteristics parameters of motions (Gaverdovsky, 2003; Asseman, 2004).

The degree of fatigue, the speed of its increasing, and the speed of recovery after training depend on the specific physical fitness that is the basis of the special endurance. The quality of performing complex gymnastic elements and combinations is related to value of VO_2max per kg body mass of the gymnasts. Aerobic capacities influence on training loads and its quality in training units. This can be associated with slowing down the development of fatigue, increased metabolic acidosis that allow for long-term concentration and exercising for longer periods of time with maximum precision.

Thus presented data reflect higher stability of coordination capacities and regularities of their changes in gymnasts with greater aerobic capacity. Their interrelation may be used for evaluation of specific for gymnast special endurance. These data also indicate the one of the ways to provide "functional excess" in resistance to fatigue phenomena in order to provide high speed of recovery and efficiency of performing complex in coordination gymnastic exercises during the whole training session or preparation cycles. It can be assumed that changes in aerobic capacity at various stages of the annual cycle and many-years preparation reflect the evolution of the adaptability of gymnasts to training loads.

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Cite this article as: Sawczyn, S., Biskup, L., Zasada, M., Mishchenko, V. (2018). Special Endurance of Young Gymnasts: The Role of Aerobic Capacity in Fatigue Development in the Training. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 59–70. DOI: 10.18276/cej.2018.3-06.

EVALUATION OF THE RESULTS OF SURGICAL TREATMENT AND REHABILITATION OF CUBITAL TUNNEL SYNDROME

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Abstract The aim of this study was to evaluate the results of surgical treatment and rehabilitation of cubital tunnel syndrome patients. We treated 21 patients with cubital tunnel syndrome, comprising 12 women and 9 men aged 45 to 58. The syndrome affected 13 left and 8 right upper limbs. According to the modified McGowan classification patients experienced varying levels of change: 17 (81%) patients, grade 3; 3patients (14%), – 2B; 1patient (5%), – 2A. The following patients qualified for surgical treatment: those with pain in the medial side of the elbow joint, those with advanced dysaesthesia and weakness in the motor activity of the hand, and those with changes causing subluxation of the ulnar nerve. All patients were treated surgically through anterior transposition if necessary epineurotomy.The rehabilitation process included exercises involving stretching, relaxing and strengthening of muscle and improvement of the mobility of the elbow. Neuromobilisation and automobilisation exercises were conducted. Patients were taught the correct positioning of the upper limb during work and physical activity. After 12 months, the research results were rated according to the modified criteria of Wilson and Krout. In 16 (76.2%) patients the results were excellent; in 16 (19%) good and in 1 (4.8%) fair.
It was found that the vast majority of patients with advanced changes caused by cubital tunnel syndrome and subluxation of the ulnar nerve can achieve excellent and good results from decompression and transposition of the ulnar nerve and competent rehabilitation treatment.

Key words cubital tunnel syndrome, subcutaneous anterior transposition of the ulnar nerve

Introduction

Cubital tunnel syndrome (Latin: syndroma canalis ulnaris) is one of the most common neuropathies of the upper extremities. The causes of damage to the ulnar nerve are single or repeated injuries, nerve subluxation, compression of ligaments, or degenerative or congenital changes. Nerve compression is promoted by valgity of the elbow, shallowness of the groove, or stretching of the ligaments of the elbow. Cubital tunnel syndrome can occur due to overloading of limbs, destabilisation of the elbow or inflammation of the attachment of muscle to the medial epicondyle. The syndrome frequently occurs in athletes performing throws in disciplines such as: javelin, hammer

throw, baseball, tennis and golf, and among workers packing goods, working as cashiers, or using vibrating tools (Dziak, Tayara,1999; Trehan, Parziale, Akelman, 2012). Conservative treatment rarely brings improvements, most often surgical treatment is necessary. In the development of cubital tunnel syndrome, pain occurs around the medial epicondyle along with dysaesthesia and weakness in the hand's ability to grip. The pains often appear in the form of numbness or tingling but are not very severe. Initially dysaesthesia includes hypersensitivity and, subsequently reduced sensation in fingers IV and V. Functional disorders involving movement include paralysis of the flexor muscles of the elbow and wrist and the flexor digitorum profundus, followed by hyperextension of the metacarpophalangeal (MCP) joint, inability to separate fingers II–V and interosseous muscle atrophy (Deskur, Prowans, 2004; Dziak, Tayara,1999).

Surgical treatment of cubital tunnel syndrome can be performed using the open or endoscopic methods. The treatment involves decompression of the ulnar nerve or anterior transposition with displacement – subcutaneous, intramuscular, or submuscular – of the nerve. When stretching the ulnar nerve in the groove, it is advisable to notch the medial epicondyle. If signs of compression and swelling are found in the rostral part of the ulnar nerve, a epineurotomy is performed. Internal neurolysis is not recommended. In cases of subluxation of the ulnar nerve when bending or straightening the forearm, anterior transposition of the nerve is recommended. At the time of surgery, complications related to damage to nerve or blood vessels may be experienced. Following anterior transposition, compression of the nerve by the arcade of Struthers or fascial band between the heads of the flexor carpi ulnaris may occur (Gokay, Bagatur, 2012; Kamat, Jay, Benoiton, Correia, Woon, 2014; Trehan et al., 2012). The severity of changes in cubital tunnel syndrome can be determined according to the Mc Gowan classification (Gokay, Bagatur, 2012; Rokicki et al., 2013).

Material and methods

In the years 2008–2013, 21 patients with cubital tunnel syndrome, comprising. 12 women, and 9 men aged 45 to 58, were treated. Treatment and testing was carried out at the SP Regional Hospital in Nowogard by the authors. X-ray examinations and EMGs were conducted on patients prior to the clinical trial. Attention was paid to Tinel's sign, Froment's sign, the junction between fingers II and III, elbow flexion, and the abductor muscle of the little finger. The severity of changes in patients with cubital tunnel syndrome prior to surgery, was rated according to the modified Mc Gowan classification (Gokay, Bagatur, 2012; Rokicki et al., 2013) – Table 1.

Table 1. Modified Mc Gowan classification for preoperative grading of ulnar neuropathy at the elbow

Grade	Description
1	Patients with subjective sensory symptoms, but without objective findings
2A	Patients with good intrinsic strength (4/5), without intrinsic atrophy
2B	Patients with fair intrinsic strength (3/5), with intrinsic atrophy
3	Patients with marked intrinsic atrophy and sensory disturbance

Patients with pain in the medial side of the elbow joint, advanced dysaesthesia and weakness in the motility of the hand (Mc Gowan 3) as well as those with changes causing subluxation of the ulnar nerve, such as a valgus deformity of the elbow or shallow groove, qualified for surgical treatment.

All patients were treated surgically via anterior transposition of the ulnar nerve. A minimal incision was made between the top of the olecranon and the medial epicondyle. The fascial band i.e. the fibrous arcade of the flexor carpi ulnaris, was cut. The ulnar nerve was released in the channel, between the heads of the flexor wrist. Attention was drawn to the muscular branches of nerves and blood vessels. If there were signs of trouble in the channel of the ulnar nerve and swelling of the proximal part of the nerve, an epineurotomy was performed. It was important to establish sites of compression. On finding advanced changes from cubital tunnel syndrome with subluxation of the nerve, transposition of the ulnar nerve was performed under the freed flap of skin. Attention was paid to suppression of the nerve by the arcade of Struthers or by the band between the heads of the flexor carpi ulnaris. Drainage of the wound was then instituted, with a cocoon-type dressing reinforced with a back slab plaster. On the 4th day following surgery, rehabilitation was carefully implemented. Exercises aimed at relaxing, stretching, strengthening muscles, and improving joint mobility were gradually introduced. Neuromobilisation of the ulnar nerve tract was conducted, as well as automobilisation. Exercises were applied 5 to 10 times a day for 30 to 60 seconds, 1 to 3 minutes apart. Rehabilitation was carried out under the supervision of the authors of the paper (Cemphe, Pieniążek, Pelczer-Pieniążek 2007; Kużdżał, 2009).

The test results of patients at 12 months after surgery were rated according to the modified criteria of Wilson and Krout (Gokay, Bagatur, 2012; Rokicki et al., 2013) – Table 2.

Table 2. Modified Wilson and Krout criteria for postoperative grading of ulnar neuropathy patients

Grade	Description
Excellent	Minimal motor and sensory changes and no tenderness at the incision site
Good	Loss of symptoms but a regional sensitivity continued at intervals
Fair	Improved but persistent sensory or motor changes that are milder than the preoperative status
Poor	No improvement or worsened condition

Results

The study included patients with cubital tunnel syndrome, comprising 12 women (57%) and, 9 (43%) men aged 45 to 58. The syndrome involved 13 (62%) left and 8 (38%) right upper limbs. Prior to surgery in patients with cubital tunnel syndrome varying levels of changes were rated according to Mc Gowan's classification: 17 (81%) patients were assessed at grade 3; 3 patients (14%) – at 2B; and 1patient (5%) – at 2A.

In the postoperative period we evaluated the results of treatment according to the criteria of Wilson and Krout. There were 16 (76.2%) excellent results, 4 (19%) good, and 1 (4.8%) fair (Table 3).

Table 3. Number of people with the appropriate assessment of the results of the treatment of postoperative patients with the cubital tunnel syndrome according to the criteria of Wilson and Krout depending on the severity of lesions according to Mc Gowen preoperatively

Wilson and Krout evaluation	The number of patients with appropriate severity changes cubital tunnel syndrome by Mc Gowan			Total
	2A	2B	3	
Exellend	1	2	13	16
Good		1	3	4
Fair			1	1

Discussion

Most reports state that cubital tunnel syndrome is most common in men and in the dominant upper limb (Anderton, Webb, 2010; Gokay, Bagatur, 2012; Rokicki et al., 2013). In this study the syndrome was present in 57% of women and affected the left side in 62%. Kamat et al. (2014) and Jeon et al. (2010) confirmed that the syndrome was more prevalent in women and Kanat et al. (2014) confirmed that it involved primarily the upper left limb. Perhaps this is the consequence of women, undertaking jobs previously performed by men.

Many authors have stated the variability of results for syndrome patients with cubital tunnel syndrome depending on the severity of lesions, methods of operation and methods of assessment. We present a summary of the results for similarly treated patients with cubital tunnel syndrome. Results of excellent and good were more frequent following decompression and anterior transposition of the ulnar nerve (Table 4).

Table 4. Evaluation of the results of surgical treatment of patients with cubital tunnel syndrome in the published literature

Autors	Number of treated patients	Surgical treatment	Methods of assessment of treatment	Percentages of relevant results in treated patients			
				excellent	good	fair	poor
Rokicki et al. (2013)	19	Decompression of nerve	Wilson and Krout	53	37	5	5
Gokay et al. (2012)	33	Transposition of subcutaneous nerve	Wilson and Krout	73	21	3	3
Han et al. (2014)	20	Transposition of subfascial nerve	Bishop	55	40	1	–
Jeon et al. (2010)	66	Decompression of the nerve	Messininoj	36	45	17	2

Results of treatment may also be good in elderly patients with cubital tunnel syndrome. Sreedharan, Yam, Tay (2010) reported results for 19 patients over 60 years of age following decompression and transposition of the ulnar nerve. Improved sensation was reported in 78.9% and improved muscle strength in 86.7% of patients. Kamat et al. (2014) and Nabhan et al. (2007) achieved comparable results following decompression, neurolysis and anterior transposition of the ulnar nerve.

Conclusions

1. Cubital tunnel syndrome is one of the most common neuropathies of the upper limb. This syndrome is marked by pain in the medial side of the elbow joint, dysaesthesia and weakened motility of the hand.

2. Following the diagnosis of cubital tunnel syndrome, all risk factors must be eliminated immediately and conservative treatment implemented. Lack of improvement is an indication for surgical treatment.

3. Excellent and good results can be achieved in the vast majority of patients with advanced changes from cubital tunnel syndrome and subluxation of the nerve through decompression and transposition of the ulnar nerve and competent rehabilitation.

4. The best surgical results can be achieved with rehabilitation carried out by a specialised therapeutic team.

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Cite this article as: Deskur, A., Deskur, Z. (2018). Evaluation of the Results of Surgical Treatment and Rehabilitation of Cubital Tunnel Syndrome. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 71–75. DOI: 10.18276/cej.2018.3-07.

PRINCIPAL COMPONENT ANALYSIS IN THE STUDY OF STRUCTURE OF THE BEST POLISH DECATHLON COMPETITORS FROM THE PERIOD BETWEEN 1985–2015

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Abstract The modern decathlon is a sport consisting of ten different events held over two days, played by men. Depending on the complexity of combined events, variety of events (runs, throws, jumps), the multi-stage, time-consuming and difficult training process the sport is considered as one of the most difficult. The analysis of careers of the best decathlon participants and applying advanced data-mining methods can help define the patterns occurring between each decathlon event and the final result.
The research material encompasses career data of the 25 top competitors from Poland in years 1985–2015. Principal component analysis (PCA) was used in the research in order to designate new uncorrelated variables (components), representing input data across a new plane.
Data analysis involved appointment of correlations between the events, determining the number of main components taken into account in further studies, analysis of the weight of each variable in formation of main components as well as visualisation and interpretation of results in the new plane described by the determined main components.
Through the implementation of PCA method in the process of analysis it was possible to designate over 69% of compound data volatility with the use of the first three components. The first component, comprised of seven variables, displays the largest share in the total variability. The study of the relationship between variables in the new plane displayed strong correlations between sprint events (100 m, 110 m hurdles) and long jump and pole vault. No correlations between the 1,500 m run and other events were found.

Key words decathlon, sport career, principal component analysis

Introduction

The modern decathlon is a combined event, played by men, comprising ten events held over two days. This complex form of track and field competition is characterised by varied composition of events (runs, throws, jumps), differing in terms of effort and technique and requires a competitor to possess a high degree of motor skills (speed, strength, endurance) and perfectly mastered technique (IAAF, 2018; Quercetani, 2000).

Decathlon is one of few athletic competitions, in which the results from each component are recalculated into points and summed, with the final result being the measure of the competitor's proficiency. Because of the number of component events and complexity of that combined event the training process of a decathlon competitor is a lengthy, multi-stage and difficult process (Socha, 1977).

Because of that, scientific research of decathlon's structure turned out to be crucial, as it could assist the competitors and trainers in optimising the training process. Over the course of the years there were numerous works, which employed advanced mathematical and statistical methods in analysis. Furdal (1986) highlighted in his paper the importance of studies carried out as early as in the 1950s and 60s (Karvonen, Niemi, 1953; Zaciorski, Godik, 1963) which utilised factor analysis for checking the correlations between the total result and component events. In the same work the author carried out an analysis on the basis of 158 world's best decathlon competitors using oblique component method and principal profile method, which resulted in determining tree correlated event groups in decathlon and separation of six main competitor profiles in relation to acquired results (Furdal, 1986).

Currently, there are also works, in which advanced calculation methods (e.g. factor analysis, configural frequency analysis) were used to define the type of competitors which are successful in decathlon because of their aptitude and motor skills (Bilić, 2015; Stemmler, Bäumler, 2005), as well as to study the hidden structure of decathlon (Ertel, 2011).

Park, Zatsiorsky (2011) in their work used the principal component analysis (PCA) to designate new variables describing the structure of decathlon on the basis of the results of competitors competing during Olympic Games in years 1988–2008. Another work the principal component analysis was used to reduce the number of variables describing the career progress of decathlon competitors competing in years 2004–2013, the results of which were used to predict the results of future events with the use of artificial neural networks (Chen, Zhang, 2016).

The goal of the work was the implementation of advanced data-mining methods, in this case – the PCA method, to reduce the number of variables describing the structure of decathlon on the basis of career progress of the 25 best Polish competitors, competing in years 1985–2015.

Methods

The study material involved data of career progress of the 25 best Polish competitors from Poland, competing in years 1985–2015. The competitors were selected on the basis of their personal records and length of their sports careers, which could be no shorter than 5 years. The accumulated data (194 participations) involved the best entries of competitors in each year of their careers, containing final results and partial results from each of the ten component events expressed in metric units and in points. The database was created on the basis of the provided PZLA result database (PZLA, 2016) and published PZLA statistical yearbooks for the period between 1985–2015 (PZLA, 1985–2006).

In studies carried out to reduce the number of variables characterising the career progress of the best Polish decathlon participants the principal component analysis (PCA) was used. PCA method involving matrix operations is used for multidimensional data exploration, projection and visualisation. PCA analysis results in new principal components which are linear combinations of vectors subjected to analysis regarding maximisation of variance description. The designated components, which represent multidimensional input date in a new plane contain the most important data regarding volatility of the acquired and analysed study material. Reduction of data dimensionality is carried out by studying the acquired eigenvalues of principal components describing the percentage of described

data variance. The choice of the appropriate number of components included in the following analyses is based on the criterion adopted by the researcher, e.g. Kaiser's criterion, scree test or others. This thesis utilises Kaiser's criterion, which eliminates from further analysis principal components of eigenvalues of less than 1 (Bishop, 2006; Daszykowski, Walczak, 2008; Hardle, Simar, 2007; Kassambara, 2017; STHDA, 2018).

All analyses were carried out with the use of R programming language with additional packages (R Core Team, 2018).

Results

Utilising the accumulated research material involving the career progress of 25 Polish decathlon competitors competing in years 1985–2015 basic statistics were designated, presented in Table 1. The highest result in the group of Polish combined event competitors was achieved by Sebastian Chmara, who scored 8566 pts in Alhama de Murcia in 1998, taking first place and beating Polish record (Matthews, 2013).

Table 1. Basic statistics

Variable	Symbol	Unit	Best results		Worse results		$\bar{x}$		Me	
Personal best	PB	[pt]	8566		7253		7652		7551	
100 M run	X100m	[s] [pt]	10.76	915	12.44	567	11.36	783	11.33	789
Long jump	HJ	[m] [pt]	7.75	997	5.49	479	6.91	794	6.96	804
Shot put	SP	[m] [pt]	16.03	853	9.56	459	13.10	674	13.31	687
High jump	HJ	[m] [pt]	2.15	944	1.56	434	1.95	759	1.95	758
400 M run	X400m	[s] [pt]	48.27	896	57.08	518	51.12	765	50.89	774
110 M hurdles	X110m	[s] [pt]	14.32	934	18.70	459	15.41	803	15.31	813
Discus throw	DT	[m] [pt]	49.86	867	22.11	312	38.91	643	38.98	644
Pole vault	PV	[m] [pt]	5.20	972	2.40	220	4.23	687	4.28	695
Javelin throw	JT	[m] [pt]	67.48	851	28.25	275	51.59	613	51.96	618
1,500 M run	X1500m	[s] [pt]	260.12	811	346.01	324	287.92	634	286.68	639

In accordance to Daszykowski, Walczak (2008) the element being decisive in decreasing the data dimensionality through substitution of some variables by new variables being linear combinations of original parameters are correlations between individual variables. In order to study the correlation between component events of decathlon and the impact of these events on the final result of the competition the values of Pearson's linear correlation were calculated r_{xy}, which are presented in Figure 1.

By analysing the values of correlation coefficient, a crucial and significant impact of nine component events on the final result of decathlon was observed ($r_{xy} > 0.59$). The smallest correlations were found between total result and the 1,500 m run where the value of correlation coefficient was at the level of -0.29. By studying the correlations between the component events of decathlon, the highest values were determined for discus throw and shot put ($r_{xy} = 0.72$) as well as 100 m run and long jump ($r_{xy} = –0.64$) and 400 m run where the r_{xy} was at 0.64. The smallest correlations were observed for the variable of 1,500 m run. The exception was the correlation of that event with 400 m run, which amounted to $r_{xy} = 0.53$.

The result of the PCA analysis was creation of 10 new principal components describing the total variance of original data. On the basis of the acquired eigenvalues of components (Table 2), which describe value of variance of contained data, and the assumed Kaiser's criterion the first three principal components were chosen, which describe 69.77% volatility of acquired data. The graphic interpretation of eigenvalues of principal components is shown in Figure 2.

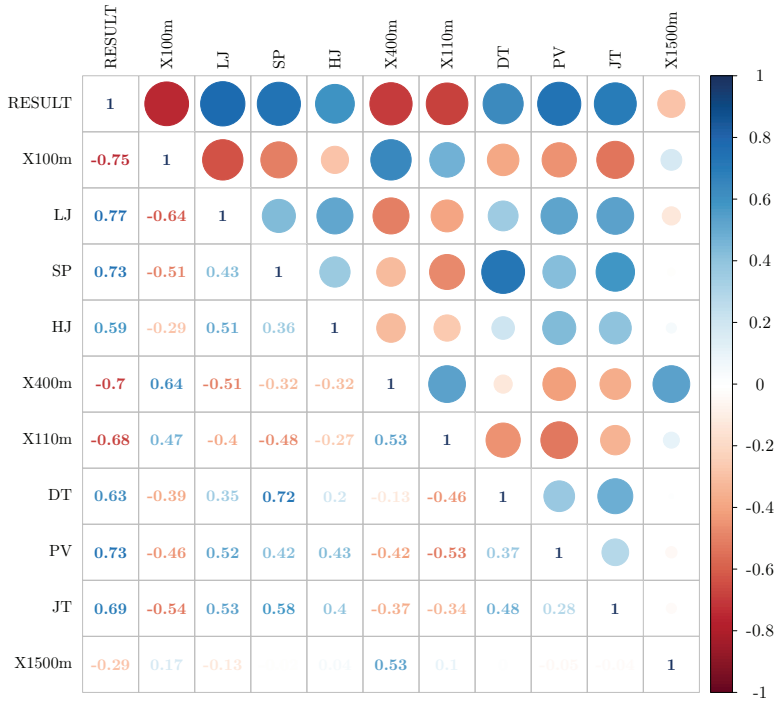

Figure 1. Values of Pearson's linear correlation coefficients for 10 component events

Table 2. Eigenvalues of principal components

	Eigenvalues	Percentage of variances	The cumulative percentage of variances
Component 1	4.53	45.27	45.27
Component 2	1.45	14.49	59.76
Component 3	1.00	10.01	69.77
Component 4	0.83	8.32	78.09
Component 5	0.62	6.17	84.27
Component 6	0.50	4.97	89.23
Component 7	0.34	3.44	92.67
Component 8	0.34	3.41	96.09
Component 9	0.23	2.33	98.42
Component 10	0.16	1.58	100.00

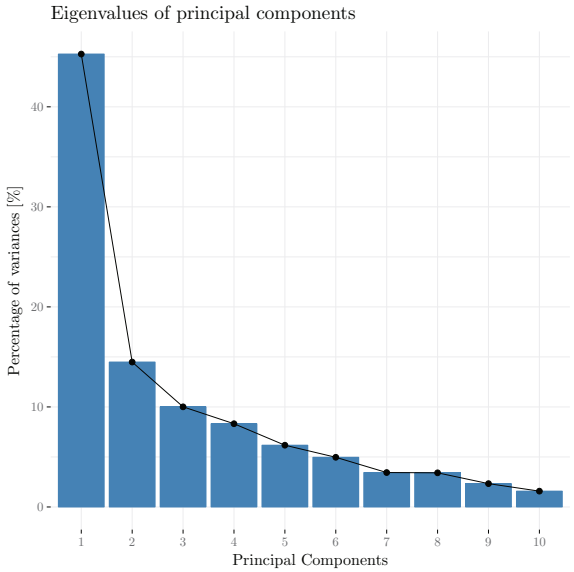

Figure 2. Eigenvalues of principal components – graphic interpretation

Each variable of original data included in PCA analysis has a specific contribution to building new components. Percentages of variables describing the first three principal components were placed in Table 3, and their graphic form was presented in Figures 3–5. By studying the structure of the first component seven explanatory variables were found, among which the highest percentage was reached by variables corresponding to events: 100 m run, long jump and shot put. The remaining variable with values above the red dashed line (Figure 3) have a less severe but important impact on the quality of information stored in the first principal component. The second principal component (Figure 4) is composed of variables storing the result data of 1,500 m run (43.81%), 400 m run (26.45%) and discus throw (14.89%). The structure of the last principal component (Figure 5) contains the variable of high jump, which explains 39.95% of variability and variables of discus throw and 1,500 m run.

Table 3. Share of each variable in each principal component (%)

Variable	Component 1	Component 2	Component 3
X100m	13.85	1.67	0.09
HJ	13.32	0.37	9.81
SP	12.62	8.99	8.88
HJ	7.21	1.05	39.95
X400m	10.64	26.45	0.00
X110m	10.91	0.07	3.21
DT	8.96	14.89	21.74
PV	10.43	0.05	5.32
JT	11.12	2.68	0.13
X1500m	0.95	43.81	10.87

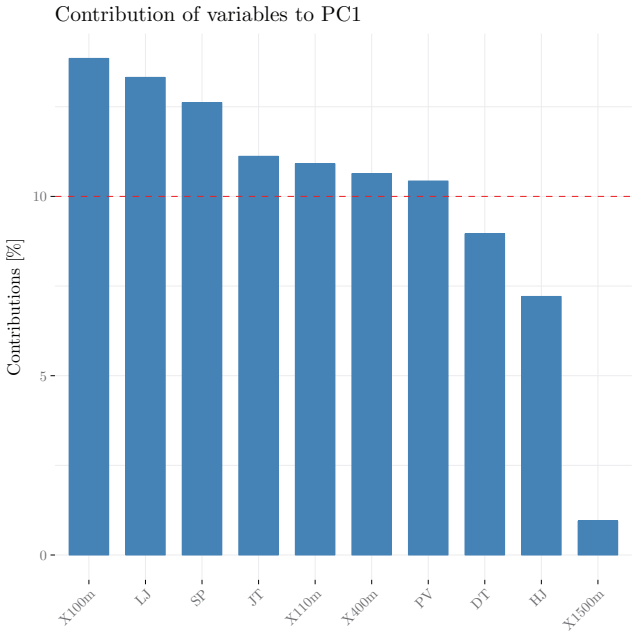

Figure 3. Share of variables in the first principal component

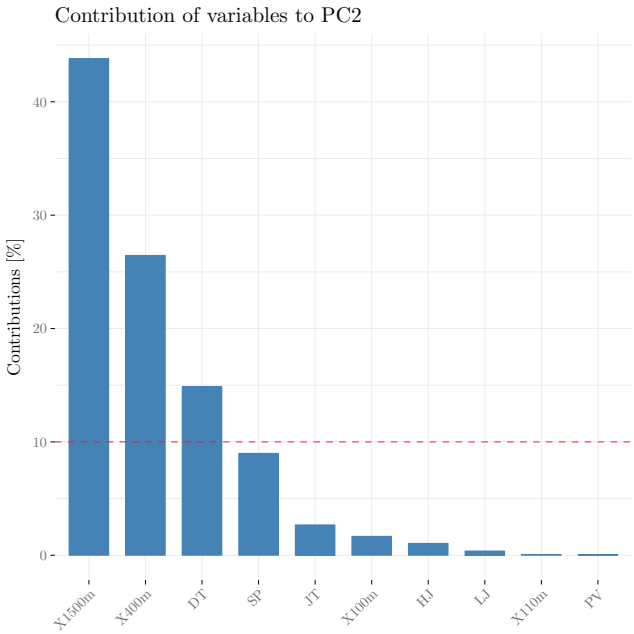

Figure 4. Share of variables in the second principal component

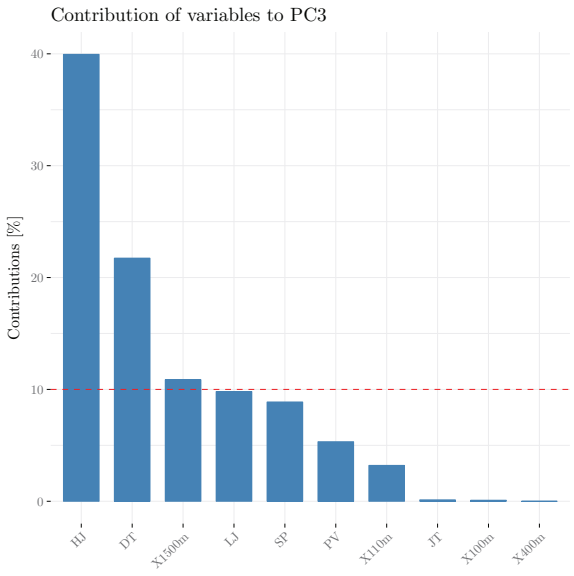

Figure 5. Share of variables in the third principal component

The structural correlation between variables and principal components can also be illustrated on a factor map (Figures 6–8). Factor map is used for graphical presentation of result on a plane described by the created principal components, and shows the correlation strength and coefficient of correlation between variables and the quality of their representation, as well as helps define (description, naming) the principal components. On the basis of the chart creating the plane described by the first two principal components (59.76% of the total variance) and drawn variables (Figure 6) a significant correlation between 100 m and 110 m sprints was observed, which negatively correlate with long jump and pole vault events. Also observed was a positive correlation between throw events. The variable storing data on the results achieved by decathlon competitors in 1,500 m run does not indicate correlation with the rest of the variables, except for an insignificant correlation with 400 m run. In the chart described by the second and third component a large share of 1,500 m run in creation of the second component was observed, which, similarly as before, does not indicate correlations with other events except for 400 m run. By projecting the variables on the ordinate axis formed by the third component a large share of high jump variable and discus throw can be seen in the structure of the third variable which confirms the previous observations (Figure 5). In addition, in the spaces described by the included principal components, significant positive relationships between the variable discus throw and shot put (DT and SP) were observed.

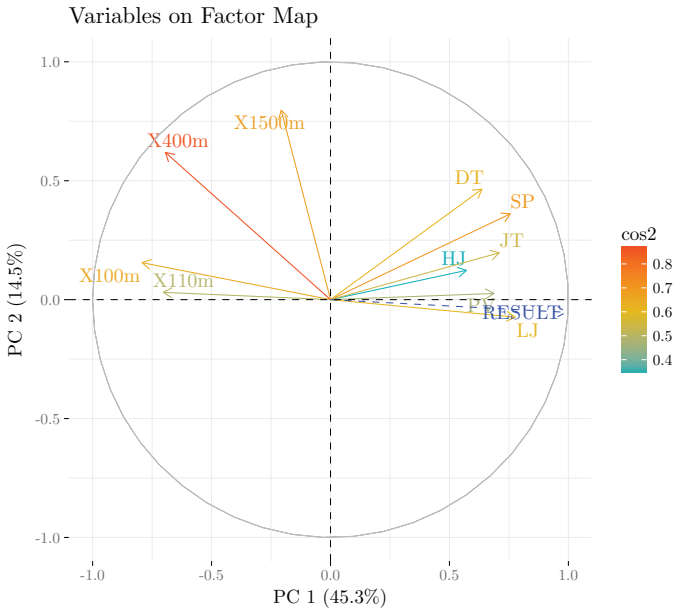

Figure 6. Projection of variables on the factor map described by the first and second principal component

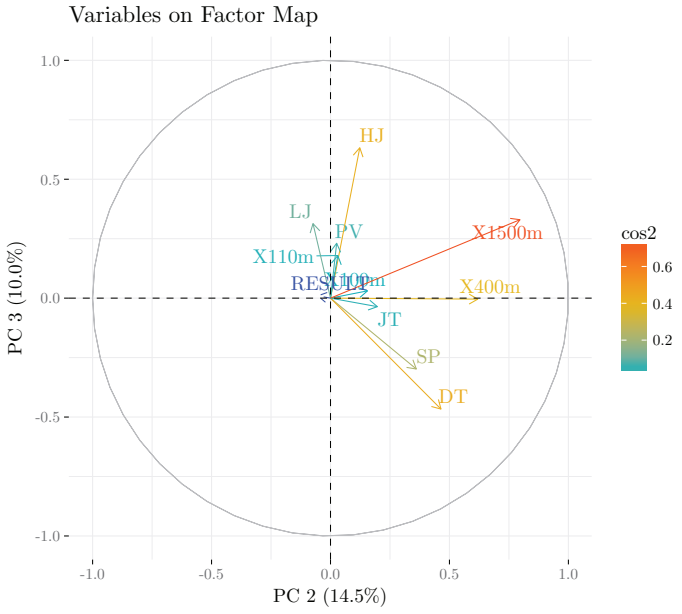

Figure 7. Projection of variables on the factor map described by the second and third principal component

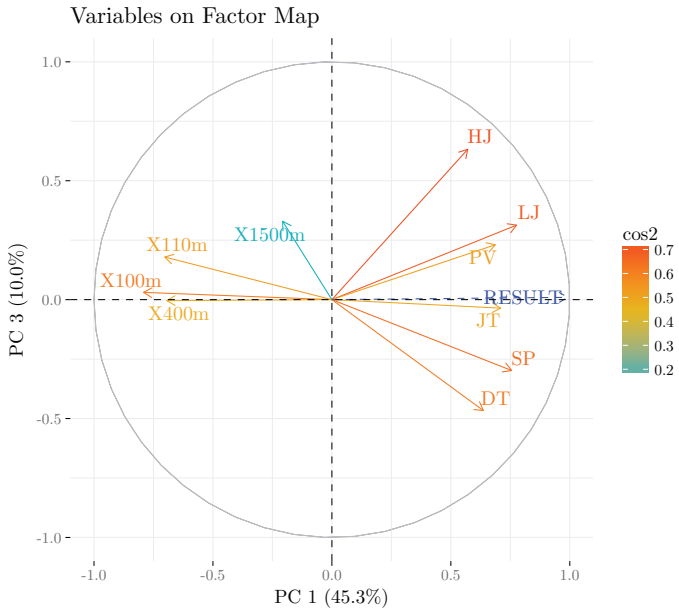

Figure 8. Projection of variables on the factor map described by the first and third principal component

Discussion

Study of the structure of decathlon, searching for correlations between component events and the final result can be practically implemented and significantly improve the training process of a competitor. Mathematical and statistic methods were often used in research involving the complexity of this form of combined event competition. The acquired research material encompassing the career progress of 25 Polish decathlon competitors, competing in years 1985–2015, was used in principal component analysis (PCA) in order to decrease dimensionality and define the structure of new components representing the collected data.

The results achieved by the athletes in all ten events have significance and impact on the final, total result of decathlon (Furdal, 1986; Nowak, 1989). Pearson's linear correlation analysis carried out on the studied group has shown that almost all events have significant impact on the final results (for nine events $r_{xy} > 0.59$). The event with the smallest influence on the final result of a decathlon competitor is 1,500 m run, with the value of correlation coefficient at –0.29. Because 1,500 m run has a completely different character from the remaining events (endurance performance versus speed/strength preparation), while the motor requirements of decathlon involve mostly speed/strength effort (Vana, 2003), the speed/strength preparation is an important, while difficult to achieve, element of physical preparation (Dziadek, Iskra, Przednowek, 2016). On the basis of the analysis of the value of correlation coefficients between the decathlon competition, it was found that the most dependent on each other were the discus throw and shot put ($r_{xy} = 0.72$). Similar observations were observed by Furdal (1986), who analysed the results obtained by the 158 athletes starting in 1980-1983, who determined the largest dependencies for these two throwing competitions ($r_{xy} = 0.61$). Walaszczyk (1998), presented analysis relationships between the decathlon

components in three successive Olympic cycles (1985–1996) among of the 50 world's best decathletes, the largest correlation values in the analysed periods also concerned the discus throw and shot puts (r_{xy} = 0.59; 0.56; 0.76). The importance of the relationship between the discus throw and the shot put was also presented by Socha (1977) and Iskra (1990), where the calculated correlation coefficient were, respectively, r_{xy} = 0.56 and r_{xy} = 0.54.

Principal component analysis led to definition of 10 new components describing the total variance of the collected research material. Thanks to the Kaiser's criterion employed by us, the further part of the studies involved only the first three principal components which described over 69% of variables. The same criterion was used by Park, Zatsiorsky in their work (2011), who also employed three principal components, which described 70% of data variance regarding the competitors' performance competing in Olympic Games in years 1988–2008.

By using the factor map and internal structure of components it was observed that the first component (describing 45.3% of the total variance) is composed mostly of variables involving 100 m run and long jump, which are typical speed events and shot put which involves mostly strength and technique. The composition of the second component (14.5% of the total variance) involves considerable information content regarding 1,500 m and 400 m runs, which require endurance and run tactics, while the third component (variance at 10.0%) is composed mostly of high jump, the results of which are determined by speed and explosive strength of lower limbs of the competitor.

Conclusion

The employed method of principal component analysis and the obtained results allowed us to draw the following conclusions:

- the first three principal components describe 69% variables of acquired data,
- the largest share in the total variance is displayed by the first principal component, which is described by 100 m run, long jump and shot put,
- the study of the relationship between variables in the new plane displayed strong correlations between sprint events (100 m, 110 m hurdles) and long jump and pole vault which suggest that speed and power are most important abilities in selection for the decathlon,
- no significant correlations between the 1,500 m run and other events were found.

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Cite this article as: Dziadek, B., Iskra, J., Przednowek, K. (2018). Principal Component Analysis in the Study of Structure of the Best Polish Decathlon Competitors from the Period between 1985–2015. *Central European Journal of Sport Sciences and Medicine*, *3* (23), 77–87. DOI: 10.18276/cej.2018.3-08.

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ISSN 2300-9705

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