ORIGINAL ARTICLE

Performance-associated parameters of players from the deaf Czech Republic national soccer team: a comparison with hearing first league players

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Abstract

Background Testing of performance-associated parameters is a routine requirement in high-performance sports. Limited information is available regarding the anthropometrical, physiological and biomechanical characteristics of deaf soccer players.

Objective The primary purpose of this cross-sectional, descriptive study was to investigate possible performance-associated differences between the deaf Czech Republic national team soccer players and hearing counterparts from the Czech Republic First League.

Methods Seventy-four male soccer players (31 deaf and 43 hearing, ≥ 17 years of age) underwent laboratory testing that included measurement of autonomic cardiac activity, anthropometrical parameters, vertical jump performance, and maximal aerobic capacity via an incremental running test.

Results Compared with the hearing players, deaf players were shorter ($p = 0.012$), had more body fat ($p < 0.001$), a higher resting heart rate ($p = 0.001$), and ratio of Ln rMSSD to R–R interval length ($p = 0.006$), while maximal power output ($p < 0.001$), maximal oxygen uptake ($p = 0.003$), were significantly lower. After correcting for body fat percentage, the differences were not significant except for maximal power output value.

Conclusions Being at a disadvantage, the deaf soccer players differ from their hearing counterparts in various physiological or morphological parameters assumed to be associated with sports performance in soccer. However, the differences were minimized when taking 10% of body fat as a cut point into account. Thus, reduction in body fat percentage to the 10% level may be considered as one possible strategy for improving both the physical fitness and adaptability level of the studied deaf soccer players.

Keywords Deaf athlete · Team sport · Maximal oxygen uptake · Body composition · Heart rate variability

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Introduction

Hearing loss has multiple and heterogeneous causes. In general, the causes include aging, noise, disease, and genetics. There are three main types of hearing loss: conductive (a structural or mechanical problem that interferes with sound conduction through the canal, tympanic membrane, or ossicles), sensorineural (damage to the cochlea or the auditory nerve), or a combination of both [1]. For purposes of competitions sanctioned by the International Committee of Sports for the Deaf [2], being "deaf" is defined as "a hearing loss of at least 55dB pure tone average in the better ear (3-tone pure tone average at 500, 1000 and 2000 Hz, air conduction, ISO 1969 Standard)". Hence, this definition includes both, deaf and hard of hearing (milder hearing loss and ability

to communicate well in the hearing community) athletes, regardless of age of onset.

Having a hearing loss does not confine individuals to competitions for the physically challenged as many deaf athletes compete with and against hearing opponents [3, 4]. However, team sports that include both hearing and deaf athletes, in general, do not ensure equal conditions for both groups of athletes (e.g. interpersonal interactions) and so exclusive competitions for deaf are typical, including soccer [5] (see also the International Committee of Sports for the Deaf [ICSD] or the European Deaf Sport Organisation [EDSO]). Specific techniques that assist deaf athletes during training and competition include visual methods of orientation and communication, use of sign language or lip reading [1, 3, 6], and consideration of related medical problems (e.g. balance difficulties) [7]. Utilization of hearing aids (external cochlear implants or listening devices for communication purposes) is not permitted during competition [8].

Regular testing of performance-associated parameters that includes anthropometrical, physiological and biomechanical measures is a requirement in high-performance sports. Soccer is an intermittent, high-intensity sport where strength and endurance are considered important co-factors for performance [9, 10]. Therefore, laboratory testing of appropriate performance-associated variables in soccer is based on the measurement of aerobic endurance performance (namely maximal oxygen uptake [VO_{2max}]), the anaerobic threshold, work economy [11, 12], somatic profile [13], explosive leg strength [11], and cardiac vagal activity [14, 15].

Most publications on deaf or hard of hearing athletes report psychological or sociological issues associated with this population, focusing on the idea that deaf sport is a vehicle for deaf integration [6, 8, 16]. However, to ensure optimal development of talent identification, academy level and high performance programs, research is required to identify the physical and physiological characteristics of these athletes. To the best of our knowledge, this is the first study to compare selected somatic, endurance, strength and autonomic nervous system performance-associated parameters between deaf soccer players and their hearing counterparts.

Methods

Participants

The sample consisted of 74 male soccer players (hard of hearing or deaf: $n = 31$ members of the Czech Republic national team; hearing: $n = 43$ players from the Czech first league as controls) aged ≥ 17 years. The players underwent the laboratory testing procedures described below as a part of their mid-season testing in the winter of the 2016/2017

season. Inclusion criteria for participation in this study were as follows: each player had to (a) participate in the entire laboratory testing protocol, and (b) be free of any health problems that may have limited performance in any laboratory test. This research was performed in accordance with the ethical guidelines outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University, Olomouc, Czech Republic. All the players participating in the study were volunteers and had provided their written informed consent before commencement of the study.

Testing procedures

The entire testing protocol was performed between 8 am and 14 pm on a single day in the following order: a resting 10-lead electrocardiogram (ECG) assessment (Delta 60D, Cardioline, Cavareno, Italy) with subsequent blood pressure measurement to exclude any cardiovascular contraindications for testing, a resting autonomic cardiac activity assessment, basic anthropometrical measurements, vertical jump test, and an incremental running test.

Autonomic cardiac activity assessment

Monitoring of autonomic cardiac activity was performed between 8 and 10 am through heart rate variability (HRV) assessment in a laboratory where the ambient temperature ranged from 22 to 24 °C. Timing of the HRV evaluation followed the recommendation of Malik and Camm [17] who highlighted the importance of considering circadian oscillations in HRV [18]. During the measurement, each player was shielded from acoustic and visual disturbances. To determine resting HR and HRV variables, an ECG signal was measured at a sampling frequency of 1000 Hz using DiANS PF8 (DIMEA Group, Olomouc, Czech Republic). HRV assessment was performed during a time-modified orthoclinostatics test (1 min supine- 5 min standing- 5 min supine) according to Botek, Krejčí, Neuls, and Novotný [19]. The ECG record was examined and all premature ventricular contractions, missing beats and any artefacts were manually filtered. A set of 300 artefact-free subsequent RR intervals was obtained from each phase. HRV level was quantified by time domain analysis using the root mean square of successive difference of RR intervals (rMSSD). rMSSD is regarded as an index of vagal activity [15] and is thought to be resistant to the effects of breathing frequency [20]. Skewed distribution of rMSSD was corrected using logarithm transformation (Ln).

Anthropometrical measurement

The soccer players had their body height (cm) and body weight (kg) measured using the SOEHNLE 7307 (Leifheit, Nassau, Germany). The percentage of body fat (%BF) and fat free mass (FFM) were determined using bioimpedance analysis (Tanita BC-418 MA, Tanita, Tokyo, Japan). Bioimpedance is a complex quantity composed of resistance which is caused by total body water and reactance that is caused by the capacitance of the cell membrane [21] with various values subsequently derived and estimated. Considering estimation of body fat, studies on used type of Tanita found out both, overestimation (1.68% when compared to hydrostatic weighing; [22]) and underestimation (2–6% in various categories of men and women when compared to dual-energy X-ray absorptiometry; [23]) of %BF, depending on regression analyses against a reference standard used.

Vertical jump test

Participants performed three single maximal effort counter-movement jumps (CMJ) after a warm-up (dynamic stretching of the lower limbs for 1-min and one submaximal CMJ). A 10-s rest period was provided between each CMJ. The starting position for the CMJ was an upright posture with the arms down at the sides. Participants initiated the CMJ by lowering the body and swinging the arms back (shoulder hyper-extension) and then jumped up as high as possible while swinging the arms downward, forward, and upward (shoulders moving from hyper-extension to flexion) [24]. Vertical ground reaction force was measured on two parallel force platforms (AMTI OR6-7-1000, Advanced Mechanical Technology, Watertown, MA, USA) with a sampling frequency of 200 Hz. A quiet standing period of 2 s was recorded prior to the initiation of each CMJ to ensure an initial velocity of zero and to calculate the body weight. The jump height (JH) was calculated from the force-time curve as described by Vaverka et al. [25]. The maximal JH of three CMJ repetitions was considered as recorded and compared between groups.

Incremental running test

Each player underwent an incremental running test on a treadmill (Lode Valiant, Groningen, Netherlands) to obtain VO_{2max} and HR_{max}. The exercise protocol consisted of a 4-min warm-up period (2-min at 8 km·h^{-1} with 0% inclination and a further 2-min at the same speed with a 5% inclination). The speed was then increased to 10 km·h^{-1} for 1 min with the gradient kept at 5%. For each minute thereafter speed increased by 1 km·h^{-1} with the gradient at 5% up to maximal speed of 16 km·h^{-1}. From this stage only the inclination increased by 2.5% every minute until exhaustion.

Breath-by-breath ventilation and gas exchange were measured (Ergostik, Geratherm Respiratory, Bad Kissingen, Germany) during the exercise with the data averaged to 30 s for analysis. Gas and flow analyzers were recalibrated before and after each testing using gases of known concentration and a 3-l calibration syringe. During the test, the ambient temperature (20−24 °C) was maintained by the air-conditioning system with relative humidity kept between 40 and 60%. The VT level was assessed based on selected ventilatory variable (VE, VE/VO$_2$ and VE/VCO$_2$ ratios) responses according to Wasserman et al. [26]. The following criteria were used to document that VO_{2max} was achieved: (i) a lack of increase in VO$_2$ upon an increase in work rate, (ii) respiratory exchange ratio > 1.10 [27]. VO_{2max} was recorded as the highest VO$_2$ value in the final 30 s of the test [28]. Heart rate response was measured continuously using a chest strap (Polar, Kempele, Finland). Maximal power output (P_{max}) was calculated according to following formula [29]: $P = (0.2\,s + 0.9\,sg + 3.5)/10.5$, where: P is relative power output (W·kg^{-1}), s is speed (m·min^{-1}), and g is fractional grade.

Statistical analysis

For statistical analysis, Statistica 12.0 software (StatSoft, Tulsa, OK, USA) was used. Data were expressed as a mean ± standard deviation. For the tested variables, differences between groups (deaf vs. hearing players) were valuated using a two-sample t test. Statistical significance was set at $p < .05$. The practical significance of the difference between groups was evaluated using effect size calculated as Cohen's d [30]. The following threshold values for effect size were adopted [31]: <0.2 (trivial), ≥0.2 (small), ≥0.6 (moderate), ≥1.2 (large), ≥2.0 (very large).

Analysis of covariance (ANCOVA) was performed to evaluate differences between groups when considering %BF as covariate. The ANCOVA model incorporated two regression lines $y = a_1 + b \times (\%\text{BF} - 10)$ and $y = a_2 + b \times (\%\text{BF} - 10)$ for deaf and hearing players, respectively, where a_1 and a_2 are intersections at 10% of fat and b is the slope expressing change per 1% of fat. Intersections a_1 and a_2 were calculated for 10% of fat instead of 0% of fat because 10% of fat was regarded as typical for soccer players [32, 33].

The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request.

Results

Comparison of anthropological variables is displayed in Table 1. Body weight and BMI were not statistically significant between deaf and hearing soccer players. However, deaf players were significantly shorter compared with hearing

Table 1 Comparative analysis of selected anthropometrical, physiological, and biomechanical variables in deaf/hard of hearing (Deaf) and hearing (Controls) soccer players

	Deaf (n=31) Mean ± SD	Controls (n=43) Mean ± SD	p	d
Age (years)	23.4 ± 4.8	23.9 ± 5.0	0.650	0.107
Body height (cm)	178.6 ± 5.9	182.2 ± 5.8	0.012	0.610
Body weight (kg)	76.9 ± 9.9	77.4 ± 7.5	0.779	0.066
BMI (kg·m^2)	24.1 ± 2.7	23.3 ± 1.2	0.093	− 0.401
Body fat (%)	14.2 ± 4.3	10.2 ± 2.6	< 0.001	− 1.174
Fat-free mass (kg)	65.8 ± 7.4	69.6 ± 7.1	0.030	0.522
VO_{2max} (ml·kg^{-1}·min^{-1})	53.6 ± 6.8	57.5 ± 4.0	0.003	0.735
VT (%VO_{2max})	87.1 ± 2.6	86.2 ± 4.8	0.327	− 0.233
P_{max} (W·kg^{-1})	5.40 ± 0.43	6.35 ± 0.33	< 0.001	2.513
CMJ (cm)	38.5 ± 5.4	40.5 ± 4.2	0.070	0.433
HR_{max} (beats·min^{-1})	187.9 ± 6.8	187.4 ± 10.3	0.807	− 0.058
HR_{rest} (beats·min^{-1})	62.0 ± 10.5	55.0 ± 7.8	0.001	− 0.787
Ln rMSSD (ms)	4.20 ± 0.54	4.25 ± 0.59	0.682	0.097
Ln rMSSD/RR (× 1000)	4.27 ± 0.44	3.88 ± 0.67	0.006	− 0.665

SD standard deviation, *p* statistical significance; *d* Cohen's effect size, *BMI* body mass index, *VO_{2max}* maximal oxygen uptake, *VT* anaerobic ventilatory threshold, *P_{max}* maximal power output, *HR_{max}* maximal heart rate, *HR_{rest}* resting heart rate, *CMJ* countermovement jump, *Ln rMSSD* natural logarithm of root mean square successive difference of R-R intervals, *Ln rMSSD/RR* ratio of Ln rMSSD to RR interval length

soccer players. In addition, deaf players had significantly higher %BF, and significantly lower FFM compared with hearing players. Therefore, the ANCOVA (Table 2) was performed to determine whether body composition influenced any of the measured physiological variables.

Comparison of the raw data for the physiological variables (Table 1) revealed that deaf players had a significantly lower VO_{2max}, and higher Ln rMSSD/RR and HR_{rest} compared with hearing players. After correcting for %BF, these differences were no longer significant (Table 2). However, P_{max} was significantly lower in deaf players for both the raw values and after correcting for %BF.

Discussion

The primary purpose of this study was to compare performance-associated variables in the Czech Republic deaf national soccer team players with their hearing counterparts from the Czech First Soccer League.

The primary findings of this study were that the deaf soccer players had lower maximal aerobic capacity (moderate effect), maximal power output (very large effect), and explosive power (small effect) compared with the control group. Regarding the somatic variables, the deaf soccer players were shorter (moderate effect) and had significantly higher %BF (moderate effect but close to the threshold of large effect) and lower FFM (small effect). There was no difference in supine cardiac vagal regulation between the groups. However, the deaf soccer players demonstrated a significantly higher resting HR compared with the control group (moderate effect). Once corrected for %BF (with cut point set to 10% of fat), the differences were no longer significant except for P_{max} value which remained to be a variable with the most significant difference between the tested groups of players.

Generally, aerobic fitness levels of professional soccer players correspond with VO_{2max} values of 60 ml·kg^{-1}·min^{-1} [32] or even higher [34]. High VO_{2max} is acknowledged to play a key role in recovery (lactate turn over) between the exhaustive power-demanding sprints and high intensity

Table 2 Analysis of covariance of physiological variables in deaf/hard of hearing (Deaf) and hearing (Controls) soccer players and body fat percentage as covariate

	Deaf (n=31) a_1 ± 95% CI	Controls (n=43) a_2 ± 95% CI	p_G	b ± 95% CI	p_S
VO_{2max} (ml·kg^{-1}·min^{-1})	56.8 ± 2.2	57.7 ± 1.4	0.486	− 0.76 ± 0.33	< 0.001
VT (%VO_{2max})	86.6 ± 1.8	86.1 ± 1.2	0.672	0.12 ± 0.28	0.404
P_{max} (W·kg^{-1})	5.65 ± 0.15	6.36 ± 0.10	< 0.001	− 0.059 ± 0.022	< 0.001
CMJ (cm)	39.9 ± 2.1	40.6 ± 1.4	0.589	− 0.35 ± 0.32	0.036
HR_{max} (beats·min^{-1})	185.2 ± 4.0	187.3 ± 2.7	0.390	0.65 ± 0.61	0.036
HR_{rest} (beats·min^{-1})	59.2 ± 4.0	54.8 ± 2.7	0.073	0.69 ± 0.61	0.027
Ln rMSSD (ms)	4.23 ± 0.26	4.25 ± 0.18	0.899	− 0.009 ± 0.040	0.657
Ln rMSSD/RR (× 1000)	4.12 ± 0.27	3.87 ± 0.18	0.116	0.035 ± 0.040	0.088

a_1 intersection at 10% of fat in deaf/hard of hearing group, *CI* confidence interval, *a_2* intersection at 10% of fat in hearing group, *p_G* significance of group factor, *b* slope expressing change per 1% of fat *p_S* significance of slope, *VO_{2max}* maximal oxygen uptake, *VT* anaerobic ventilatory threshold, *P_{max}* maximal power output, *CMJ* countermovement jump, *HR_{max}* maximal heart rate, *HR_{rest}* resting heart rate, *Ln rMSSD* natural logarithm of root mean square successive difference of R-R intervals

periods during soccer match play [11]. There is also a positive correlation between an increase in VO_{2max} and distance covered during a match as well as the number of sprints performed [35]. Based on our results, it is clear that the deaf soccer player's exhibited lower aerobic fitness compared with professional, hearing soccer players. Our results agree with Güzel et al. [36] who also found a lower aerobic capacity after performing a 20-m shuttle run test in national Turkish deaf soccer players (estimated $VO_{2max} = 52.5$ ml·kg^{-1}·min^{-1}) compared with their age-matched professional soccer players (estimated $VO_{2max} = 59.5$ ml·kg^{-1}·min^{-1}).

Similarly to aerobic capacity, significantly lower P_{max} values were identified in the deaf players compared with the hearing soccer players. While P_{max} of the controls (6.35 W·kg^{-1}) was in accordance with corresponding values ascertained by the same methodology in soccer players aged 17–39 (6.3–6.6 W·kg^{-1}) and published elsewhere [32], P_{max} of the deaf players only reached 85% of the controls' values.

Soccer involves a variety of motor components that involve explosive leg power, i.e. acceleration, movement velocity and, or jumps [37]. The mean height for the CMJ in the control group was higher compared with the deaf soccer players, however the difference was not statistical significance ($p = 0.07$). Nevertheless, compared with the control group, Helgerud et al. [11] reported substantially higher CMJ heights (mean = 60 cm) in elite soccer players competing in the Champions' League.

In the present study, the Ln RMSSD variable, which is vagally related [15], did not differ significantly between the groups in spite of a lower resting HR in the hearing players. A training-related decrease in resting HR is generally accepted as marker of endurance adaptation level [38]. However, a significantly higher Ln rMSSD/RR was found in the deaf players compared with the controls (moderate effect). A discrepancy between resting HR values and vagal activity was previously reported in well trained athletes in a meta-analysis by Sandercock et al. [39]. They reported that increased vagal modulation was responsible for the initial reduction in resting HR, and other factors such as changes in heart geometry and/or a reduction in an intrinsic HR may be responsible for further decreases in resting HR with ageing without further changes in HRV. Akgul Ercan et al. [40] compared autonomic function via heart rate recovery between deaf athletes and their hearing counterparts and similarly to the present study found no significant differences in vagal activity. Hence, deaf athletes seem to have the same level of vagal activity (adaptability) that is closely related to enhancement in VO_{2max} as in hearing junior soccer players [41]. Therefore, it is presumable that hearing loss does not have a significant effect on resting cardiac vagal regulation in deaf athletes who regularly perform physical activity.

According to Gil et al. [13], somatic profile plays an important part in soccer performance. The mean %BF typically ranges from 7 to 12% among national senior soccer teams [42]. In our study, both groups showed a comparable level of body weight. However, bio-impedance body composition analysis revealed a significantly higher %BF in deaf players compared with control. In addition, the professional soccer players had 4 kg more FFM compared with the deaf players. Botek et al. [32] reported that %BF increases slightly with age in professional soccer players from 16 to 39 years, and reaches up to 12.5% in the oldest group. In the present study, the less favorable body composition of the deaf players would have impacted on their performance of the endurance and strength motor tasks. After correcting the analyzed parameters for %BF dependence, only P_{max} values remained significantly different between the deaf and hearing soccer players. Thus, one of possible strategies for improvement in performance level could be related to changes in body composition of the studied deaf soccer players when considering also nutritional recommendations and control.

Regarding our primary findings, it is important to consider that athletes who are deaf/hard of hearing are a diverse population with varying degrees of hearing loss, educational backgrounds, different communication methods, and athletic skills [6]. Typically they do not experience the same training conditions, quantity of competitions (games) per year or receive the same economic support as elite hearing athletes do. According to the Czech Republic Deaf Football, the national team squad has approximately 30 players and majority of them (65%) are employees with working duties on a daily basis and the remainder consists of students. The national team does not have any regular collective training sessions except for training camps lasting 2–4 days with a friendly match included, three or four times per year (usually before qualification matches). During the year, most of the deaf national team players perform in lower (or local) soccer leagues usually with hearing players. Taken together, we propose that the lower endurance fitness and power endurance in the deaf soccer players is most likely related to lower training load and games compared with their professional hearing soccer colleagues who usually perform between 5–6 training sessions and one or two matches per 1 weekly microcycle in the Czech Republic. In addition, the size of the national team soccer squad is very limited and exclusive to sensory deficit. The expectation is that national team deaf players would exhibit weaker performance levels compared with their hearing counterparts who undergo multi-level talent selection and professional training on a regular basis (see also Czech Republic Deaf Football for a schedule). However, to date this is the first study to provide comparative data. Based on the results, Czech Republic Deaf Football is now able to use the data to provide guidelines regarding National level player expectations and the development of deaf football players.

Finally, despite the findings of the present study demonstrating discrepancies in performance characteristics of National level deaf soccer players compared with their hearing counterparts, an outcome of this study is to help in the development of deaf soccer. It is important to remember that deaf sport is a social institution within which deaf people exercise their rights to self-determination through organization, competition, and socialization surrounding deaf sport activities. Hence, a primary function of sporting events for deaf people is to serve as a catalyst for the socialization of a low-incidence and geographically dispersed population [8].

Although presented research includes data from the whole Czech national team of the deaf soccer players, it should serve as a pilot study more likely than a reference study because of limited sample size. Hence, our findings are limited to the tested groups of athletes. To draw more valid conclusions, international comparative studies on these issues with greater sample sizes of deaf soccer players are necessary.

Conclusion

To conclude, we feel that expectable differences in talent selection, training doses, number of competitions per year, background support are probable causes of differences in selected performance-associated variables between the deaf and hearing soccer players, mostly in power endurance, body composition, and aerobic capacity. On the other hand, a reduction in %BF to the 10% level when paying special attention also to nutritional issues and energy balance may be considered as one possible strategy for improving both the physical fitness and adaptability level of the studied deaf soccer players.

Internet links

http://www.ciss.org/International Committee of Sports for the Deaf.

http://www.czechdeaffotbal.cz/lCzech Republic Deaf Football.

http://www.edso.eu/European Deaf Sport Organisation.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interests.

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