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GENDER-BASED DIMORPHISM OF AEROBIC AND ANAEROBIC CAPACITY AND PHYSICAL ACTIVITY PREFERENCES IN DEAF CHILDREN AND ADOLESCENTS

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ABSTRACT

Purpose. Research on the hearing impaired has revealed that the rate of change of physical fitness characteristics between both genders may be different than that of the hearing. The aim of the study was to verify the gender-based differentiation of aerobic and anaerobic capacity in a group of deaf children and adolescents (aged 10–18 years) and to evaluate their physical activity preferences. **Methods.** A semi-longitudinal study was conducted, with data collected three times over a period of two years. Aerobic capacity was measured by the PWC_{170} cycle test, anaerobic capacity by the Wingate test. A questionnaire was used to evaluate the physical activity preferences and favored leisure activities of the participants. **Results.** Significant gender-based differences were found in the aerobic and anaerobic capacity of the deaf boys and girls. A moderate correlation was noted for leisure time preferences. **Conclusions.** Deaf children feature no gender-based differences among their physical activity preferences. Environment plays a major role in stimulating the behavior of deaf children and adolescents.

Key words: aerobic and anaerobic capacity, sexual (gender) dimorphism, deafness

Introduction

Disabilities, especially those that affect the musculoskeletal system, play a large role in reducing physical activity levels. However, often at times individuals with sensory impairments are not perceived as having the same limitations in performing physical activity as those with physical disabilities. This is especially so with hearing impairments, which are usually not regarded as limiting physical activity, although research on this subject has provided contradictory results. Many researchers state that the physical abilities of the deaf are highly differentiated and even sometimes lower than those found among an average hearing population [1–5], concluding that this may be the consequence of how physical education is shaped and taught to the deaf. A study by Ellis [6] revealed that one of the most important factors motivating deaf youth in performing physical activity is the emotional support and involvement of parents. A similar conclusion was reached by Dummer et al. [2], stating that there are no differences in the motor skills of deaf children and their hearing peers. This group of authors believes that the introduction of early intervention and special education programs already at the preschool age helped bridge any supposed impediment. Moreover, they recognized that environmental factors (type of school, lifestyle, parental attitude as well as their involvement in physical activity, and the availability of free play opportunities) also play an important role in motor development. Liberman et al. [4, 7] drew attention to the importance of several environmental factors, in particular on how physical education classes were conducted through the use of special programs and the role of physical education teachers in providing a behavioral role model for participation in physical education. An additional factor noticed by auxologists and teachers of the deaf is the difference in interest in various forms of physical activity based on gender, which is believed to be a reflection of what physical activity can actually be performed [2, 8].

Research has confirmed that the gender difference between males and females is already visible at the preschool age and includes not only interest in various forms of physical activity but also motility [9]. The ontogenetic development of motor and morphological skills has been described as highly variable. Motor skills are largely the result of environmental conditioning, hence dimorphic variation cannot be as clearly defined as in the case of somatic characteristics. Therefore, it is difficult to expect that dimorphic traits in motility would not be present even when a hearing impairment is present. However, a few studies that have been conducted on the hearing impaired found that the rate and pace of characteristics that can emerge to differentiate both genders may be different than those among the hearing [3, 10–13]. Among girls, fewer differences were found to exist between those hearing and deaf than in the case of boys. Comparative studies on the physical development of deaf boys and girls have revealed significant differences in favor of girls. One of many conclusions reached by such studies was that deaf girls develop physical and motor skills better than boys [10–15]. It was also noted that deaf girls learn new motor skills quicker and show little or no differences when compared with their hearing peers than in the case of deaf boys. In contrast, deaf boys often showed significantly greater motor deficits than their hearing peers [2]. Haubenstricker and Seefeldt's findings [8] on the hearing helped theorize that the ability to learn basic motor skills is more similar between deaf boys and girls than among their hearing peers. Instead, the delay experienced by deaf boys in learning new motor skills may be caused by them presenting a physical fitness level lower than among the hearing.

The aim of this study was to verify what gender differences exist among a group of deaf children and adolescents (10–18 years old) in their ability to perform aerobic and anaerobic tasks as well as what their physical activity preferences. In light of the formulated objective, the study was guided by the following research questions:

1. What is the preferred physical activity of deaf male and female youth?
2. Is gender a factor that differentiates the deaf in their ability to perform aerobic and anaerobic tasks?

It was assumed that the preferred physical activity is an important factor differentiating aerobic and anaerobic exercise capacity.

Material and methods

Students attending special education schools for the deaf and hard of hearing from the Polish cities of Katowice, Kraków, and Racibórz comprised the target population. A sample was selected by adopting the criteria used in modern audiology as based on Parving [16]. The main criterion for inclusion was for the student to have been diagnosed of profound hearing loss (prelingual deafness) before the age of three and experiencing sensorineural hearing impairment. All cases where the etiology of deafness was unknown were excluded from the study. All of the participants had normal intelligence as well as showed no signs of any physical disabilities that could impair movement.

The final sample included deaf students of both genders within the calendar age groups of 9.6–10.5 years, 12.6–13.5 years, and 15.6–16.5 years, where 17.7% had inherited deafness, 55.4% were prenatal cases, and 26.9% suffered a hearing impairment after the postnatal period up to age three. The study design was designed to be semi-longitudinal in nature and divided into three age groups within a 10–18 year old spread. It was conducted three times in 2004, 2005, and 2006 (all in the month of October) on the same deaf students within the mentioned three age groups, allowing the same age groups to be observed (9.6–12.5, 12.6–15.5, and 15.6–18.5 years old) (Tab. 1).

A self-designed questionnaire was used to evaluate the physical activity preferences of the participants. It contained closed-ended questions with multiple-choice answers on how they enjoyed spending their leisure time. The questionnaire was completed with the help of a sign language interpreter who also provided instructions on how to complete the exercise tests measuring aerobic and anaerobic capacity. Each exercise task was preceded by a demonstration with a complete explanation of the instructions and conducted by the same research team each time.

The study was approved by the Bioethics Committee of Scientific Research at the University School of Physical Education in Katowice, Poland as part of a project funded in part by the State Committee for Scientific Research. In addition, the legal guardians of the participants were informed of the nature of the experiment and provided their written consent. The participants were informed they may at any time leave the study without providing any reason and reminded that their personal information would remain private in accordance with all applicable data privacy laws.

Physiological data was collected by lung vital capacity as well as the aerobic and anaerobic capacity of the participants was measured. Vital capacity (VC) was measured in l/min by use of Pony Graphic 3.7 spirometer (Cosmed, Italy). Respiratory rates were measured twice as per the manufacturer's recommendation. Prior to taking a measurement, the participant was asked to breathe calmly for a short period of time and then inhale and exhale as hard as possible, performing a maximum inhalation and maximum exhalation. After exhaling the remaining residual air volume was measured.

Aerobic capacity was assessed by $VO_{2max} \cdot kg^{-1}$ and the PWC_{170} cycle test on an 828E cycle ergometer (Monark, Sweden), which from a technical point of view was the most accommodating for the participants due to their impairment. The task was thoroughly explained to the participants and motivation was provided throughout the test. First, the workload on the cycle ergometer needed to maintain a heart rate of 170 beats per minute was calculated (a higher value in the PWC_{170} test denotes that more work needs to be performed based on a correctly functioning cardiovascular system). It was determined that two five-minute trails at 30 and 60 W for

Table 1. Participants grouped by age and gender

Year	10 (12)		13 (15)		16 (18)		2004–2006
	Girls	Boys	Girls	Boys	Girls	Boys	*n*
2004	6	16	6	6	12	10	56
2005	6	14	6	6	10	9	51
2006	6	15	6	6	10	10	53

Age in parentheses is the age of the participants at the conclusion of the study girls and 50 and 100 W for boys would be adequate. Throughout the test the participants' heart rate was monitored. PWC_{170} was calculated by the formula:

$$PWC_{170} = N_1 - N_2 \cdot \frac{170 - f_1}{f_1 - f_2},$$

where:
N_1 – first test workload,
N_2 – second test workload,
f_1 – heart rate at the fifth minute of the first test,
f_2 – heart rate at the fifth minute of the second test.

Maximal oxygen uptake (VO_{2max}) was then estimated based on the Astrand-Ryhming nomogram by taking into consideration steady heart rate at submaximal effort [17]. This provided two variables that could be used to assess aerobic endurance: maximal aerobic power (PWC_{170} [W/kg]) and and maximal oxygen uptake (VO_{2max} [ml/kg x min]).

Anaerobic capacity was measured by the 30-second Wingate Test, which is a non-invasive method that is suitable for repeated use and considered to be a reliable and accurate measure of anaerobic capacity, as anaerobic processes meet almost 90% of the overall energy demands of the test [18]. The test also registers the power output of a participant as a function of time (throughout the 30 second period of the test) as it increases and then decreases as the effects of fatigue set in. Analysis of power output as a function of time indicates that humans produce maximum power between the first 3–6 seconds of the test, followed by steady decrease until completion. This reveals the nature of the energy conversion process in the working muscles.

The test was performed with the use of a different cycle ergometer (model 829, Monark, Sweden) that measures the duration of each pedal revolution. After receiving a visual cue, the participant's task was to reach a maximum pedaling frequency as fast as possible and maintain this speed for 30 seconds. The load was matched individually to each participant by taking into account their body mass, age, and sex (75g per kg). Changes in power output were determined by the duration of each pedal revolution. The test was preceded by a five-minute warm-up on the cycle ergometer with a load suitable to reach a heart rate of 140–150 beat per minute.

Anaerobic capacity and power output were measured with the following variables: maximal anaerobic power – MAP [W], average anaerobic power – AAP [W], time to reach maximal power – TMP [s], time under tension – TUT [s], and the rate of power loss – RPL [%]. Data were recorded and calculated by using MCE ver. 2.0 computer software.

All statistical analysis was performed with Statistica v. 7.1 (Statsoft, USA) and Microsoft Excel software. The mean ($\bar{x}$), median, minimums and maximums, standard deviation (SD), and measures of skewness (SK) and kurtosis (KU) were calculated for data that were expressed as a ratio variable. Normal distribution was assessed with the Shapiro-Wilk test. Univariate ANOVA and correlation analysis using Spearman's rank correlation coefficient (r_s) was also used. The results were treated as statistically significant at $p < 0.05$.

The sexual dimorphism of the participants' somatic characteristics were determined by the differences of the mean values in each successive year. However, several studies have shown that sexual dimorphism is more accurately measured by indicators that define body proportions and not individual morphological characteristics. Developmental differences between the studied boys and girls were determined by Mollison's index of sexual dimorphism (SDI) [19]:

$$\text{SDI} = \frac{\bar{x}♀ - \bar{x}♂}{\text{SD}♂},$$

where:
SDI – the indicator of sexual dimorphism,
$\bar{x}$♀ – the arithmetic mean of the girls' characteristics,
$\bar{x}$♂ – the arithmetic mean of the boys' characteristics,
SD♂ – the standard deviation of the boys' characteristics.

Dimorphic differences were treated as significant when the difference between the means ($\bar{x}$) was larger than the standard deviation (SD) of the group of males. The absolute value of the tested variable would indicate the degree of differentiation: the larger the value the larger its value of one standard deviation away from the mean of the boys' results. A positive value would indicate that this characteristic is in favor of females.

Results

The responses obtained from the questionnaire found that the boys were decidedly less physically active than the girls, with a large majority of them preferring to spend their leisure time passively by watching TV or playing computer games (94.2% and 77.7%, respectively). However, the majority of boys reported that their more actively spent leisure time consisted of bicycling and team sports (80.5%), which was in contrast with the girls who preferred calmer activities such as playing outside and taking walks (51.8%). The results of the questionnaire indicated a lack of statistically significant differences in the leisure activity preferences of the deaf boys and girls. A moderate correlation was found between the boys' and girls' preference for passive forms of physical activity ($r_s = 0.629$, $p < 0.05$) although no significant relationships were found among active forms of physical activity (Tab. 2, 3).

Physical fitness was analyzed by measuring aerobic and anaerobic capacity. Analysis of the indicators of aerobic capacity and vital capacity (VC) found a statistically significant difference between the boys and girls only in PWC_{170} [W/kg]. Only the youngest group of girls

Table 2. Preferred leisure activities by the deaf girls and boys

	Type of activity	Boys $n = 35$	%	Girls $n = 27$	%
Passive	TV	8	22.8	12	44.4
	Computer	25	71.4	9	33.3
	Reading books	1	3.2	2	7.4
	Social games	2	5.7	4	14.8
Active	Bicycling	20	57.7	9	33.3
	Swimming	3	8.6	3	11.1
	Taking walks, playing outdoors	4	7.1	14	51.8
	Skiing	2	7.4	4	14.8
	Team sports	8	22.8	4	11.4

Table 3. Spearman's rank correlation coefficient (r_s) the deaf boys and girls with regard to their preferred leisure activities

Passive leisure activities

	Girls	Boys
Girls	x	0.629
Boys	0.629	x

Active leisure activities

	Girls	Boys
Girls	x	0.143
Boys	0.143	x

achieved better results than the boys, with the later tests finding that the boys achieved significantly better results up to the age of 18 ($f = 5.6$; $p < 0.03$). Gender had no statistically significant effect on the rate of maximal oxygen uptake, only age was a significant factor differentiating both groups. A decline of VO_{2max} values was noticed in both the boys and girls. A somewhat different picture is seen in the case of VC, whose values progressively rise over time, although no statistically significant differences were found between the boys and girls (Tab. 4).

The sexual dimorphism index found dimorphic variation in favor of the males for PWC_{170} above the age of 12 and for VC above the age of 16. It is worth noting that the dimorphism index was highly fluctuated showing no clear trend. Furthermore, the dimorphism index calculated for VO_{2max} pointed to no differences greater than one standard deviation away from the boys' mean, which indicates that there is no significant variation between genders (Tab. 4).

Analysis of the increases in PWC_{170} and VO_{2max} finds that gender has no statistically significant effect on these values, with the only statistically significant difference found in the rate of change of vital capacity between 10 and 12 years of age (Fig. 1).

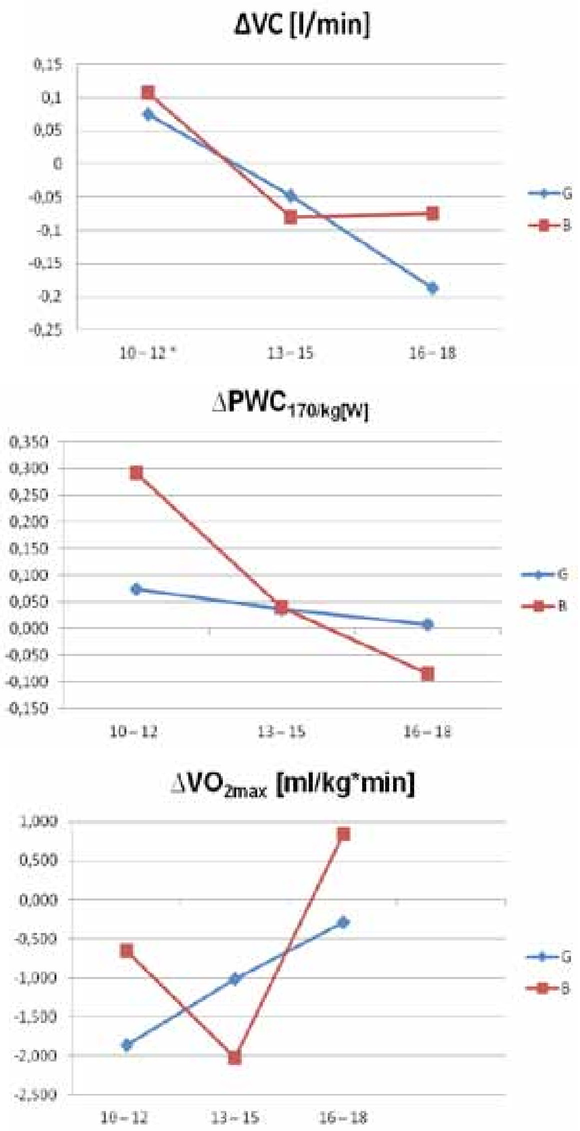
The participants' ability to perform brief anaerobic effort was based on the following five measured variables: maximal anaerobic power – MAP [W], average anaerobic power – AAP [W], time to reach maximal power – TMP [s], time under tension – TUT [s], and the rate of power loss – RPL [%]. Significant differences between the boys and girls were found for MAP and AAP (the oldest group composed of 16-, 17-, and 18-year-olds), RPL (11- and 17-year-olds), and TMP (17-year-olds), all in favor of the boys (Tab. 5). It should be noted that the time needed to reach these values was significantly higher than expected (3–6 seconds).

Anaerobic capacity assessed using the dimorphism index indicates a regular progressive trend for MAP and AAP from the age of 13 onwards, whereas the absolute values point to significant differences between genders in favor of the boys starting from the age of 16. A similar situation, although reversed, was found with RPL, which measures the rate at which fatigue sets in. This variable was found to largely characterize the girl participants (indicating a smaller tolerance to fatigue).

Table 4. Aerobic capacity and vital capacity of the deaf girls and boys

Age	VC ♀ $\bar{x} \pm SD$	VC ♂ $\bar{x} \pm SD$	VC SDI	PWC_{170} ♀ $\bar{x} \pm SD$	PWC_{170} ♂ $\bar{x} \pm SD$	PWC_{170} SDI	VO_{2max} ♀ $\bar{x} \pm SD$	VO_{2max} ♂ $\bar{x} \pm SD$	VO_{2max} SDI
10	2.0 ± 0.5	2.5 ± 0.3	–1.5	1.9 ± 0.8	1.7 ± 0.6	0.2	54.2 ± 18.8	50.2 ± 11.3	0.3
11	1.9 ± 0.4	2.3 ± 0.4	–0.8	1.6 ± 0.7	1.8 ± 0.7	–0.2	48.5 ± 18.5	49.1 ± 12.3	–0.1
12	2.14 ± 0.6	2.7 ± 0.8	–0.7	1.8 ± 0.3	2.4 ± 0.7	–0.8	48.2 ± 13.2	50.9 ± 11.3	–0.2
13	2.9 ± 0.2	3.4 ± 0.9	–0.4	1.5 ± 0.3	2.0 ± 0.4	–1.2	40.1 ± 4.0	49.2 ± 10.1	–0.9
14	2.8 ± 0.4	2.9 ± 0.6	–0.2	1.4 ± 0.2	1.7 ± 0.2	–1.6	36.6 ± 4.0	43.2 ± 3.8	–1.6
15	3 ± 0.4	3 ± 0.7	0.1	1.9 ± 0.4	2.3 ± 0.6	–0.7	40.4 ± 5.8	48.4 ± 11.0	–0.7
16	2.9 ± 0.3	3.8 ± 0.5	–1.6	1.7 ± 0.7	2.5 ± 0.7	–1.2	39.7 ± 9.4	44.6 ± 7.6	–0.6
17	2.7 ± 0.5	3.9 ± 0.4	–2.7	1.5 ± 0.6	2.5 ± 1.2	–0.9	39.2 ± 7.7	48.0 ± 13.7	–0.6
18	2.7± 0.6	3.6 ± 0.5	–1.7	1.8 ± 0.6	2.4 ± 0.5	–1.0	41.6 ± 9.3	46.1 ± 7.7	–0.6

* statistically significant difference between genders at $p < 0.05$; SDI – Mollison's sexual dimorphism index; shaded values indicate a difference in dimorphic traits (SDI > SD♂)



* statistically significant difference at $p < 0.05$
Δ – denotes change as a unit of time (year) for VC, PWC_{170}, and VO_{2max}

Figure 1. Rate of change for vital capacity and the indicators measuring the aerobic capacity of the deaf girls (G) and boys (B) among the three age groups (10–12, 13–15, and 16–18 years old)

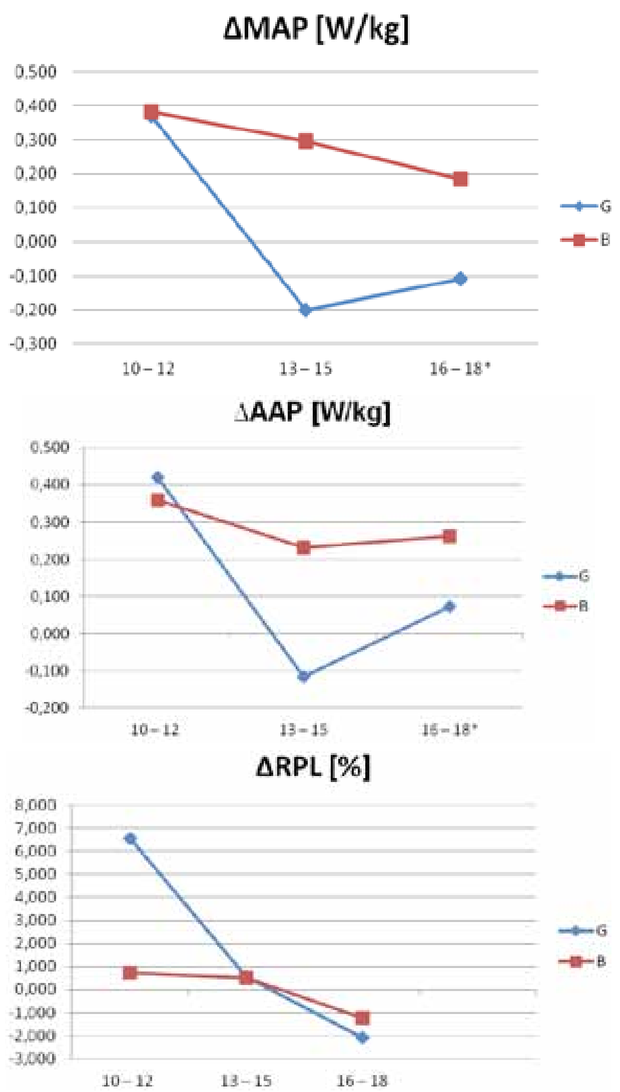
Nonetheless, the SDI index was less than one standard deviation away from the boys' means, which suggests that gender is not a differentiating factor here. The remaining variables assessing anaerobic capacity oscillated between zero and the absolute value of one standard deviation, indicating no significant differences between the genders (Tab. 5).

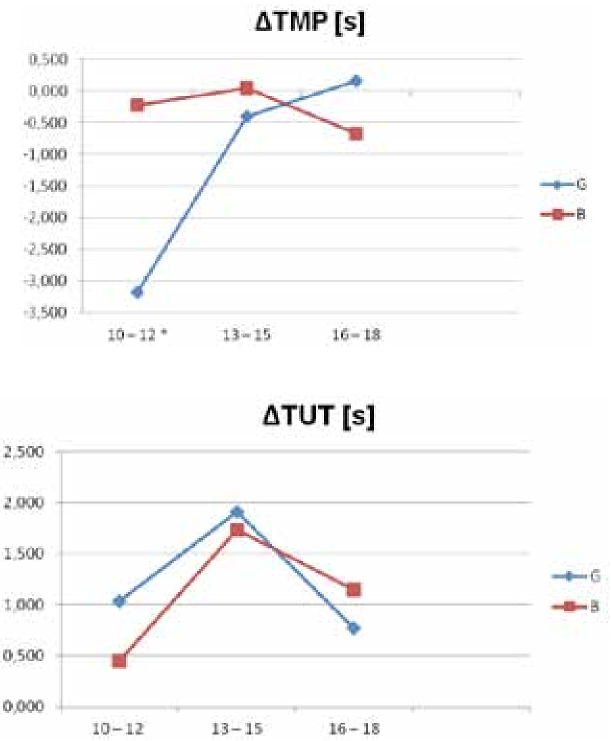
Analysis on the rate of change of the variables measuring anaerobic capacity found that gender did have a statistically significant effect on increased TMP in the youngest age group. There were no statistically significant differences in the rate of change for the remaining variables between the two genders (Fig. 2).

Table 5. Anaerobic capacity of the deaf girls and boys

Age	MAP [W/kg] ♀ $\bar{x}$ ± SD	MAP ♂ $\bar{x}$ ± SD	SDI	AAP [W/kg] ♀ $\bar{x}$ ± SD	AAP ♂ $\bar{x}$ ± SD	SDI	TMP [s] ♀ $\bar{x}$ ± SD	TMP ♂ $\bar{x}$ ± SD	SDI	TUT [s] ♀ $\bar{x}$ ± SD	TUT ♂ $\bar{x}$ ± SD	SDI	RPL [%] ♀ $\bar{x}$ ± SD	RPL ♂ $\bar{x}$ ± SD	SDI
10	5.1 ± 1.7	6.9 ± 2.0	−0.8	3.6 ± 1.7	5.4 ± 1.6	−1.0	15.2 ± 5.4	11.6 ± 4.4	0.8	1.6 ± 1.0	1.1 ± 1.3	0.4	17 ± 4.8	16.8 ± 7.8	0.1
11	5.5 ± 2.3	6.3 ± 1.5	−0.5	4.1 ± 1.9	4.9 ± 1.4	−0.5	12.7 ± 5.5	16.1 ± 7.8	−0.4	3.08 ± 2.2	2.1 ± 2.6	0.3	24.7 ± 7.4	14.3 ± 8.1	1.2
12	5.7 ± 2.2	7.6 ± 2.1	−0.8	4.4 ± 1.9	5.9 ± 1.7	−0.9	9.9 ± 5.2	11.5 ± 4.5	−0.3	3.3 ± 2.7	1.9 ± 0.8	1.6	28.7 ± 17.1	17.6 ± 5.8	1.9
13	7.7 ± 1.2	7.5 ± 1.1	0.1	5.7 ± 0.5	6.1 ± 0.9	−0.5	12.5 ± 3.3	10.8 ± 2.8	0.6	1.6 ± 0.7	1.0 ± 1.7	−0.2	21.7 ± 9.7	14.2 ± 3.8	1.9
14	6.7 ± 1.0	8.0 ± 1.3	−0.9	5.2 ± 0.4	6.5 ± 0.9	−1.4	13.5 ± 2.5	12.0 ± 5	0.6	2.7 ± 1.2	4.7 ± 4.6	−0.4	16.9 ± 9.5	12.6 ± 5.8	0.7
15	7.4 ± 0.4	8.7 ± 1.0	−1.2	5.5 ± 0.5	7.2 ± 0.9	−1.7	12.5 ± 2.6	10.4 ± 2.8	0.7	3.6 ± 2.2	3.5 ± 2.3	0.03	22.5 ± 12.5	15.3 ± 2.6	2.7
16	6.9 ± 2.2	9.5 ± 1.2	−1.9	5.09 ± 1.7	7.5 ± 0.7	−3.1	10.2 ± 3.0	12.8 ± 5.8	−0.4	1.3 ± 1.2	1.2 ± 2.5	−0.01	25.6 ± 17.7	15.7 ± 7.1	1.4
17	7.3 ± 1.7	9.4 ± 1.8	−1.2	5.5 ± 1.1	7.4 ± 1.4	−1.4	10.2 ± 3.4	16.2 ± 6.6	−0.9	2.5 ± 1.5	2.0 ± 1.6	0.23	22.3 ± 7.9	11.1 ± 7.8	1.4
18	6.8 ± 1.4	9.5 ± 1.2	−2.2	5.2 ± 0.9	7.8 ± 0.7	−3.3	10.2 ± 1.4	11.7 ± 4.0	0.3	2.6 ± 1.3	3.4 ± 2.8	−0.3	20.4 ± 7.2	13.6 ± 6.7	1.0

* statistically significant difference between genders at $p < 0.05$; SDI – Mollison's sexual dimorphism index; shaded values indicate a difference in dimorphic traits (SDI > SD♂)





* statistically significant difference at $p < 0.05$
Δ – denotes change as a unit of time (year) for maximal anaerobic power (MAP)
AAP – average anaerobic power
TMP – time to reach maximal power
TUT – time under tension
RPL – the rate of power loss

Figure 2. The rate of change of variables measuring anaerobic capacity for the deaf girls (G) and boys (B) among the three age groups (10–12, 13–15, and 16–18 years old)

Discussion

Lung vital capacity has been medically verified to increase together with maturity, although it remains highly variable not only due to age but also gender [21]. This study confirmed the progressive rise of vital capacity in both females and males, with significant gender differences emerging after the age of 15. However, no significant sexual dimorphic differences in the rate of change of this physiological variable were found to occur in this group of deaf 10–18 year-olds.

The progressive variability of various somatic characteristics defining human development have been found to determine individual exercise capacity. This was the most visible in the oldest group of deaf participants (16-, 17-, and 18-years-old), where gender was a factor differentiating their aerobic and anaerobic capacity with males showing a considerable advantage over their female peers. These findings correspond with the results of able-bodied young adults, due in part that the physiological adaption of children's bodies to exercise significantly differs than in mature adults. These differences are particularly noticeable in exercise performed at maximal and supramaximal intensities that use predominantly anaerobic energy processes. This is due to children having a less developed ability to resynthesize high-energy resources based on anaerobic energy processes as well as a reduced ability to neutralize the byproducts of anaerobic exercise. Hence, children obtain lower measures of maximal anaerobic power and feature less tolerance to homeostatic imbalance during physical effort [22, 23]. A study by Bar-Or [18] has also shown that children's lower levels of anaerobic capacity may be caused by reduced capacity to use muscle glycogen during physical effort. This was evidenced by a slower rate of anaerobic glycolysis and lower blood lactate concentration levels in the working muscles when compared to adults. This relationship was verified in the present study of deaf children and youth, where the potential for effort increased with age and which was most visible among the group of deaf males. In terms of the differentiation between boys' and girls' anaerobic capacity, Cempla and Bawelski [24] were more critical of the opinion that boys featured a greater increase in maximal anaerobic power (MAP) relative to girls, although the results obtained in this study do not confirm their assessment.

Research on the physical activity of disabled children and youth has indicated that the hearing impaired do not see themselves as individuals who are dysfunctional when compared to the rest of the population. This group has been found to have very high self-esteem in regards to their habits and ability to perform physical exercise, while at the same time reporting that they do not feel to have physical ability levels lower than their hearing peers [25]. Among a group of disabled individuals, the hearing impaired presented a high level of physical fitness [26]. Nonetheless, these observations have been contradicted by a number of empirical studies on the aerobic and anaerobic capacity of the deaf in comparison with the non-disabled [11, 27, 28]. However, few have concentrated on the gender-based differences of the deaf's aerobic and anaerobic capacity.

Shepard, Ward, and Lee [28] examined 15 boys and 14 girls (ages 12 to 15) finding that only 40% were found to meet the norms for their age and sex. These authors pointed out that age and gender did differentiate the results, which followed a progressive trend together with age, although these changes were statistically insignificant for the group of girls. They also drew attention to the increased adiposity of the deaf, especially in the case of females, which may have contributed to this finding. Other researchers have stated that deaf children and adolescents feature lower tolerance to effort during aerobic and anaerobic testing [11, 27]. The results of this study support this hypothesis especially in the case of females. The variable measuring power loss (RPL) was significantly lower among boys in the oldest age group, which reflects their higher (better) tolerance during short-term anaerobic exercise (Tab. 5). Here, the sexual dimorphism index had a positive value as the girls' recovery process required more time, but was at the same time less than one standard deviation from the boys' mean, finding that RPL was not a characteristic that differentiates gender.

Of considerable interest is also one of the other analyzed variables, the time to reach maximal anaerobic power (TMP). The time to reach maximal power has been defined to occur at around 3–6 seconds. A surprising outcome in this study was that both the boys and girls had difficulty in reaching their maximum heart rate within this time frame. One of the only explanations for this result may be that this group was less motivated (volition). Motivation is an important factor not only for succeeding in sports but also, above all, guides individuals to engage in suitable fitness training. The concept of motivation has been defined as a "hypothetical construct" [29], as a state of readiness to take specific action stemming from both individual needs and external factors and which possesses a certain significance that cannot be completely defined through empirical evidence. Evidence of this fundamental problem can be found in the responses provided by the participants in the questionnaire on their physical activity preferences, which indicated that individual forms of physical activity were highly preferred. Yet, it is common knowledge that nothing better motivates individuals than interpersonal relationships and healthy competition. It should be taken into account that deafness is a mitigating factor in social behavior (feelings of strong alienation from both able-bodied and disabled individuals) and might have been reflected in the participants' responses. For example, their preference for these forms of physical activity are consistent with those found in a group of deaf students in Karachi, Pakistan [30]. It is worth noting that the deaf students from Karachi also ranked individual sports and forms of recreation first, while rating "improving health and the body" the least motivating factor for their participation in physical activity. Therefore, it is difficult to expect that deaf individuals would present large differences in their preferences for various forms of physical activity as is the case for the able-bodied. The findings of this study – showing a moderate correlation between girls and boys who prefer passive forms of leisure activities – allow us to assume that deafness acts to limit both the preferences and motivation for physical activity and is an issue that requires further investigation.

Conclusions

The ability to perform increasing amounts of aerobic and anaerobic work was found to increase together with age for both the deaf male and female participants. Gender-based differences were noted for aerobic (from the age of 12) and anaerobic capacity (from the age of 14). In contrast, no statistically significant differences were observed in the rate of developmental change that defines aerobic and anaerobic capacity.

The study found no differences in the physical activity preferences of the deaf boys and girls, which is believed to show that deafness is a factor that limits and, consequently, unifies what forms of physical activity the deaf prefer to engage in. It is believed that the social environment plays a large role in stimulating the behavior of deaf children and adolescents.

It was found that deaf boys perform aerobic and anaerobic effort increasingly better as they get older when compared with their female peers. Based on this study's findings (TMP) and observations made during the tests, it is believed that motivation significantly affected the attained results, possibly due to communication and interpersonal difficulties. This signifies the need for providing additional external motivation for the hearing impaired when measuring exercise capacity and during physical education classes, making this a challenge to be met by both teachers and researchers. Such a conclusion was also reached by Jonsson and Gustafsson [31], who reported that motivation is an important criterion when measuring the respiratory efficiency of the hearing impaired.

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