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# TIME PASSES – HEALTHY HABITS STAY? A LONGITUDINAL SMALL SAMPLE COMPARISON OF MUSCLE CONTRACTILE PROPERTIES, MOTOR ABILITIES AND LIFESTYLE CHARACTERISTICS OF ATHLETES AND NON-ATHLETES

Saša PIŠOT[1], Rado PIŠOT[1], Boštjan ŠIMUNIČ[1]

[1] Science and Research Centre Koper, Slovenia

*Corresponding author:*
Saša PIŠOT
Science and Research Centre Koper, Garibaldijeva 1, 6000 Koper, Slovenia
Tel.: +386 5 663 77 00
e-mail: sasa.pisot@zrs-kp.si

*ABSTRACT*

***Introduction:*** *Because healthy behaviors learned early in life are more likely to be maintained during adulthood, we aimed to investigate longitudinal changes of participants that were regularly involved in extracurricular sport activities (athletes; N = 7; 4 boys) and those that were not (non-athletes, N = 6; 3 boys)*

***Methods:*** *Participants of both groups were invited for re-assessment at the age of 27, in 2019, 12 years after they participated in a 5-year longitudinal study as adolescents (9–14 years of age, in the period 2001–07). We investigated vastus lateralis (VL) and biceps femoris (BF) contractile properties (tensiomyography), maximal running speed (photocells), anthropometric measures (bioimpedance), maximal vertical jumping height (squat and countermovement jumps on a ground reaction force plate), and lifestyle characteristics (GPAQ and EHIS surveys).*

***Results:*** *Based on Cohen's d effect size we found that athletes have lower body mass index, higher maximal running speed, better maximal vertical jumping height, and shorter BF contraction time, not found in VL, compared to non-athletes. Furthermore, athletes also exhibit healthier lifestyle characteristics such as lower sedentary time and higher daily energy expenditure than non-athletes. Athletes follow diet regimens consisting of more regular meals with more protein and indulge less in health-risk behavior (smoking and alcohol consumption). However, the self-perception of health and quality of life was lower in athletes than in non-athletes.*

***Conclusion:*** *EU regulations and the beginning of the COVID-19 pandemics prevented us from conducting a study on a more representative sample. Nevertheless, we could confirm that regular sport participation yields better physical performance* *and a healthier lifestyle but could also have a negative impact on health (injuries) and quality of life.*

***Keywords:*** *motor development, tensiomyography, sport, physical exercise, healthy lifestyle*

## ČAS MINEVA - ZDRAVE NAVADE OSTANEJO? LONGITUDINALNA PRIMERJAVA KONTRAKTILNIH LASTNOSTI MIŠIC, GIBALNIH SPOSOBNOSTI IN ZNAČILNOSTI ŽIVLJENJSKEGA SLOGA ŠPORTNIKOV IN NEŠPORTNIKOV NA MAJHNEM VZORCU

*IZVLEČEK*

***Uvod:*** *Namen raziskave je ugotoviti longitudinalne spremembe v skupini preiskovancev, ki so se redno ukvarjali z obšolskimi športnimi dejavnostmi (skupina športnikov; N = 7, 4 dečki), in tistih, ki se niso kontinuirano ukvarjali s športom (skupina nešportnikov, N = 6, 3 dečki).*

***Metode:*** *Udeleženci obeh skupin so bili povabljeni na ponovne meritve pri starosti 27 let, leta 2019, torej 12 let po tem, ko so bili v starosti od 9-14 let, v obdobju 2001-2007 vključeni v petletno longitudinalno študijo. Preučevali smo kontraktilne lastnosti mišic: vastus lateralis (VL) in biceps femoris (BF) (z metodo tenziomiografije), hitrost sprinta z letečim štartom (s fotokamerami), antropometrične podatke (z bioimpedanco), dosežek navpičnega skoka (skoki na tenziometrijski plošči s pomočjo in brez pomoči rok) ter nekatere značilnosti življenjskega sloga (anketi GPAQ in EHIS).*

***Rezultati:*** *Na podlagi velikosti učinka (Cohenove d) smo ugotovili, da imajo športniki v primerjavi z nešportniki nižji indeks telesne mase, večjo hitrost teka, boljšo zmogljivost vertikalnih skokov in krajši čas krčenja BF, kar pri VL nismo ugotovili. Poleg tega imajo športniki tudi bolj zdrave vzorce življenjskega sloga, manj sedijo in več gibajo (večja dnevna poraba energije) kot nešportniki. Nadalje prehrano športnikov sestavljajo bolj redni obroki z več beljakovinami, poleg tega imajo manj zdravju nevarnih praks (kajenje in uživanje alkohola). Kljub temu pa so športniki svoje zdravje in kakovost življenja ocenili nižje kot nešportniki.*

***Zaključek:*** *Regulativni predpisi EU za področje varovanja osebnih podatkov (GDPR) kot tudi začetek pandemije COVID-19 so nas pri izvedbi študije na bolj reprezentativnem vzorcu močno ovirali. Kljub temu smo lahko potrdili, da redno ukvarjanje s športom ohranja boljšo telesno zmogljivost, bolj zdrav življenjski slog, kar pa lahko vpliva na zdravje (poškodbe) in kakovost življenja.*

***Ključne besede***: *gibalni razvoj, tenziomiografija, šport, gibalna aktivnost, zdrav življenjski slog*

## INTRODUCTION

Most research into healthy behavior and predictors of these behaviors generally focuses on individuals' incentives to adopt positive health practices at a single point in time and do not provide a framework for how healthy behaviors may change over time. Frech (2012) indicates several reasons to investigate how and why engagement in healthy behavior changes across pivotal life course stages (Frech, 2012). First, because healthy behaviors learned early in life are more likely to be maintained during adulthood (Lau, Quadrel, & Hartman, 1990; Telama et al., 1997) and because health-promoting behaviors aid in preventing or delaying chronic or life-threatening disease. And secondly, to evaluate whether personal and social resources at one life course stage (for example during adolescence) exert an enduring or cumulative impact on healthy behaviors at later life course stages.

Therefore, sport and sport participation are viewed as an effective activity for solving problems and improving quality of life for individuals and society alike. Not just for increasing self-confidence, self-esteem, and positive body image, building our character in the form of discipline, teamwork, and responsibility, as well as our importance, but also creating motor and sport-specific skills convertible into physical capital and improving health, fitness, and an overall sense of physical well-being (Coakley, 2011).

Researchers have given considerable attention to the athlete development process, e.g., positive youth development through sport (Holt, 2008). Utilization of skeletal muscle mass to produce power is of great importance in sport. However, skeletal muscle is also indispensable for locomotion, maintenance of body posture, thermoregulation, sugar and lipid metabolism and, therefore, for general health. To realize locomotion, the muscles must produce power by generating force and shortening velocity at the same time. The speed of muscle contraction is largely determined by fiber type composition. In children, knowing the fiber type composition may be used to help in formulating an informed decision regarding taking up a sport in which the child most likely will excel. While there are numerous data on the fiber type composition of various skeletal muscle in adults and adolescents, we are aware of only seven cross-sectional studies on the fiber type composition of muscle in children between the ages of 2 months and 11 years (Bell, MacDougall, Billeter, & Howald, 1980; Glenmark, Hedberg, & Jansson, 1992; Kriketos et al., 1997; Lexell, Sjöström, Nordlund, & Taylor, 1992; Lundberg, Eriksson, & Mellgren, 1979; Österlund, Thornell, & Eriksson, 2011; Verdijk et al., 2014). Furthermore, only one study presented longitudinal data of VL composition from adolescence to adulthood (Glenmark et al., 1992) and found lower proportion of slow twitch fibers in VL muscle in girls at the age of 16 and the opposite at the age of 27. Especially where it is very difficult, for ethical reasons, to invasively measure skeletal muscle myosin heavy chain proportion or fiber type composition, tensiomyography (TMG) provides non-invasive information on changes in functional skeletal properties (Valenčič & Knez, 1997). Specifically, it was established that TMG-derived contraction time (Tc) could be used to non-invasively estimate skeletal muscle MHC type 1 proportion (Šimunič, Degens, & Rittweger, 2011).

In the period 2002–07 we followed with TMG screening >300 children in six yearly assessments. Approximately one third (107) were measured on all occasions and analyzed (Pišot et al., 2004; Šimunič et al., 2017; Završnik et al., 2016; Završnik, Pišot, Šimunič, Kokol, & Blažun Vošner, 2017). Briefly, we found that boys in general had slower muscles than girls. During early maturation in the VL muscle there is a slow-to-fast transition that begins between 6 and 10 years of age, which then appears to stabilize to adult proportions. Regular participation in sport was associated with a faster biceps femoris (BF), but not in VL, for both sexes (Šimunič et al., 2017). We also found correlation between muscle contractile properties and the running speed that was biased for both sexes. Specifically, the running speed was less correlated with VL Tc in boys than in girls. However, boys' running speed was more correlated with BF Tc than in girls (Završnik et al., 2016, 2017). Our data thus represent a first non-invasive, if indirect, indication of developmental trends in changes in muscle fiber type composition in children.

The most interesting finding for us was that regular sport participation in children aged between 9 and 14, compared to children without any extracurricular sport participation, impacted Tc in non-gravitational BF muscle but not gravitational VL muscle, in both sexes (Šimunič et al., 2017). However, it remains to be seen whether the continuation of exercise (sport participation) through adolescence to adulthood could further impact Tc in both muscles. Even more, it would be interesting to see the effect of continued sport participation on motor abilities, body characteristics and main characteristics of healthy lifestyle (nutrition, PA, habits) in the later adolescence and early adulthood of participants.

After carrying out a 5-year longitudinal monitoring of skeletal muscle contractile properties and motor abilities in >300 children within two consecutive research projects: (i) *"The role of biomechanical properties of skeletal muscle in the motor development of children"*, 2001–04; and (ii) "*Monitoring of changes in skeletal muscle biomechanical characteristics in early childhood and adolescence*", 2004–07, we invited those same subjects for a follow-up assessment in 2019 with the purpose of longitudinally investigate the changes in skeletal muscle contractile properties, physical activity level, nutrition, and health related habits.

## METHODS

In previous analyses we investigated motor abilities development in 9–14 year-old children as a factor of sex and sport participation. Furthermore, in 2019 we invited the subjects to participate again (12 years later), taking the same measurements. Furthermore, at the final assessment we investigated basic lifestyle characteristics which we obtained by a questionnaire including demographic data, physical activity, nutrition and smoking habits. Additionally, the participants were asked about their participation in organized sports, their sport injury history and important life stress events. Results of the first six assessments of vastus lateralis (VL) and biceps femoris (BF) contractile properties (tensiomyography), flying running speed (photocells), anthropometric measures (bioimpedance), and vertical jumping performance (squat and countermovement jumps on a ground reaction force plate) were previously reported in four scientific publications (Pišot et al., 2004; Šimunič et al., 2017; Završnik et al., 2016, 2017). This manuscript presents data from a 12-year follow-up in a subsample of the same participants.

## Participants and recruitment

During the recruitment we focused on inviting the 107 participants who were consistently present for all six annual measurements during the 2002–07 period. The participants came from the Slovene towns of Koper, Izola, Piran, Ljubljana, and Maribor. Due to strict personal data protection legislation (EU 2016/679, General Data Protection - GDPR), we had many problems in re-establishing contacts to recruit participants for follow-up measurements, as we only had a database with the first and last names and their elementary school. The principals of the elementary schools could not provide us with the subjects' contact information, so we had to resort to the "snowball" method and social media. We searched for potential acquaintances to contact the participants and after they agreed to be contacted, we invited them to participate in the follow-up. This was usually done through their social media (Facebook and Instagram) or by a phone call. In addition, our research organization advertised the invitation to participate in the follow-up through various media (official website, Facebook). Despite an enormous amount of time and effort invested, we kept receiving responses of interested candidates, but mostly ones who had not participated in our previous measurements from 2002–07 and thus were not eligible for the follow-up. Over the course of about six months, we were able to recruit 13 participants. We divided these participants into two groups: a group of athletes, who had regularly participated in organized sport activities during the past 12 years (athletes; N = 7; 4 boys) and non-athletes (N = 6; 3 boys). Specifically, it was evident from their questionnaire data that seven of them continuously participated in various sports from the age of 9 to 25 and were classified as athletes, while six of them had not participated in any sports for at least the past 10 years (non-athletes), although five of them had been active during the period of primary school. Table 1 summarizes the proportion of those involved in organized sport activities in three age-periods for both studied groups.

*Table 1: Proportion of participants' sport participation in the two studied groups: (i) those who continuously practiced sport from 14 to 26 years of age (athletes); and (ii) those who did not practice sport at all or only until they were 16 years old (non-athletes).*

| | Athletes | Non-athletes |
|---|---|---|
| **N** | **7** | **6** |
| **Sport participation in the age period of 9–14** | 5 out of 7 | 5 out of 6 |
| **Sport participation in the age period of 14-16** | 7 out of 7 | 2 out of 6 |
| **Sport participation in the age period of 16-26** | 7 out of 7 | 0 out of 6 |

## Measurement procedures

The follow-up measurements consisted of the following test battery: arm strength (dominant hand compression - dynamometer), TMG of two muscles, maximal running speed (7-meter sprint with flying start), maximal vertical jump height, body height, mass, mass index, and composition measurement (fat mass, muscle mass). After the tests, each subject was asked to complete a specific questionnaire consisting of several sets of validated questions (GPAQ, EHIS) to provide data on their current PA status, injury history, health status, and lifestyle to allow capturing possible factors that might influence general fitness (biomechanical muscle characteristics) at each stage of the subject's life (high school, university, and current age).

*Tensiomyography (TMG)*

The TMG method measured the contractile properties of two skeletal muscles in the dominant site (vastus lateralis – VL, and biceps femoris – BF). Each muscle was stimulated with single electric pulses, rectangular in shape, lasting 1 ms. The pulse amplitude was gradually increased until the maximum response was obtained. We saved the two largest responses for further processing and took the average of both for further analyses. We calculated two contractile parameters for each response: a maximal amplitude (Dm, in mm) to be used for the calculation of contraction time (Tc, in ms) between 10 % to 90 % Dm.

*Measurement of body composition*

After body mass and height were measured, body mass index was calculated, and composition was measured using a bioimpedance meter (Maltron BioScan 916s, UK). We ensured that participants were calm, normally hydrated, and rested for at least 20 minutes before the measurement. Fat mass was measured via a 4-point measurement.

*Maximal running speed*

After a standardized 10-minute warm-up, the maximal running speed was measured with a flying start over a distance of 7 meters. We assured plenty of room to accelerate and decelerate before and after assessment gates (Powertimer 300, Newtest, Finland), respectively. Each participant made three attempts and the best result was taken for further analysis.

*Maximal vertical jumping height*

We measured the height of the vertical jump without using hands (hands on the hips). Each participant performed three countermovement and three squat jumps on a ground reaction force plate (Quattro jump 9290AD, Kistler Ltd., Austria). The best result was taken for further analysis.

*Questionnaire*

The questionnaire designed for this study consisted of several sets of validated questions and covered basic socio-demographic data, health status and nutrition, physical/sport activity, and aspects of sedentary time. We used an adapted part of the European Health Interview survey – EHIS to assess eating habits (regular diet, type of diet) and indicators of quality of life. Additionally, physical/sport activity was assessed by a self-reported validated questionnaire The Global Physical Activity Questionnaire – GPAQ (Armstrong & Bull, 2006).

## Statistics

Due to the small sample size, we did not perform classical parametric statistical analysis. We performed the non-parametric Mann-Whitney test to compare athletes vs. non-athletes only for indicative purposes. Since small samples yield low statistical power and only large effects will end up significant, we rather calculated effect sizes – Cohen's d values – and interpreted main findings based on the effect size (low

< 0.20; moderate 0.20 ≤ Cohen’s d < 0.8 and high ≥ 0.8). For comparing correlations between lifestyle characteristics and motor abilities and muscle characteristics, we used the Spearman rho coefficient indicating significant correlations at $p < 0.05$.

## RESULTS

We were able to repeat the longitudinal monitoring of the biomechanical characteristics of skeletal muscle only on a sample of 13 (7 male) participants at the age of 27 years: 4 participants from Maribor, and 9 from Koper over 7 testing days executed in January, February, and October 2019.

In all comparisons there were no statistical differences confirmed by the Mann-Whitney test; however, due to lower sensitivity of statistical tests in very small samples, we interpreted effect sizes. Table 2 shows a progressive trend in basic anthropometric data of pooled participants indicating normal growth. When comparing athletes and non-athletes (Table 4), we found that athletes had moderately to significantly lower body mass index (effect size from 0.42 to 1.07) throughout the whole period and lower fat mass (effect size 0.65) at the age of 27 years. This is consistent with lesser sedentary time (effect size 0.55) and higher daily energy consumption (effect size 0.47) compared to non-athletes. Table 3 presents motor abilities in pooled participants. When comparing athletes and non-athletes (Table 4), we could not confirm higher running speed in athletes throughout all periods. However, countermovement and squat jump heights were higher in athletes when compared to non-athletes at the age of 27 (effect size 0.81 and 0.74, respectively). VL Tc was not lower in athletes; it was, however, lower in BF with the largest effect size at the age of 27 years (0.64).

*Table 2. Basic anthropometric data of pooled participants.*

| **Age** | **9 years** | **10 years** | **11 years** | **12 years** | **13 years** | **14 years** | **…** | **27 years** |
|---|---|---|---|---|---|---|---|---|
| **N** | **13** | **13** | **13** | **13** | **13** | **13** | **…** | **13** |
| **Body mass index / kg/m2** | 17.1 ± 2.5 | 17.9 ± 2.6 | 18.0 ± 2.9 | 19.5 ± 3.0 | 20.0 ± 2.7 | 20.3 ± 2.4 | … | 22.8 ± 3.3 |
| **Body height / m** | 1.41 ± .06 | 1.45 ± .07 | 1.49 ± .07 | 1.58 ± .07 | 1.65 ± .08 | 1.69 ± .08 | | 1.76 ± .09 |
| **Body mass / kg** | 34.3 ± 7.0 | 37.9 ± 8.2 | 40.4 ± 9.1 | 48.9 ± .11 | 54.8 ± 10.7 | 58.2 ± 9.7 | | 71.6 ± 14.4 |

*Table 3. Pooled data of selected motor abilities.*

| Age | 9 years | 10 years | 11 years | 12 years | 13 years | 14 years | … | 27 years |
|---|---|---|---|---|---|---|---|---|
| **N** | **13** | **13** | **13** | **13** | **13** | **13** | **…** | **13** |
| **Running Speed / m/s** | 5.6 ± 0.5 | 5.6 ± 0.4 | 5.7 ± 0.4 | 6.0 ± 0.4 | 6.3 ± 0.8 | 6.2 ± 0.4 | … | 6.4 ± 0.5 |
| **CMJ height / cm** | - | - | - | - | - | - | … | 29.8 ± 5.6 |
| **Squat jump height / cm** | - | - | - | - | - | - | … | 28.3 ± 5.2 |

*CMJ – countermovement jump*

*Table 4. Comparison between athletes and non-athletes*

| Group | Athletes | Non-athletes | Effect size* |
|---|---|---|---|
| **Number** | **7** | **6** | |
| **Body mass index / kg/m2** | | | |
| 9 years | 16.7 ± 2.9 | 17.7 ± 1.9 | 0.54 |
| 10 years | 17.3 ± 3.0 | 18.7 ± 2.2 | 0.63 |
| 11 years | 17.4 ± 2.9 | 18.7 ± 2.9 | 0.48 |
| 12 years | 18.7 ± 3.1 | 21.0 ± 2.4 | 0.98 |
| 13 years | 19.4 ± 3.3 | 20.7 ± 1.8 | 1.07 |
| 14 years | 19.9 ± 2.7 | 20.8 ± 2.0 | 0.42 |
| … | … | … | … |
| 27 years | 21.9 ± 3.7 | 23.1 ± 2.5 | 0.65 |
| **Fat mass / %** | | | |
| 27 years | 22.7 ± 6.4 | 23.7 ± 3.0 | 0.33 |
| **Running speed / m/s** | | | |
| 9 years | 5.5 ± 0.4 | 5.7 ± 0.5 | -0.39 |
| 10 years | 5.7 ± 0.4 | 5.6 ± 0.4 | -0.15 |
| 11 years | 5.6 ± 0.4 | 5.7 ± 0.4 | -0.41 |
| 12 years | 5.9 ± 0.4 | 6.0 ± 0.4 | -0.02 |
| 13 years | 6.0 ± 0.3 | 6.1 ± 0.3 | -0.39 |
| 14 years | 6.1 ± 0.4 | 6.3 ± 0.3 | -0.64 |
| … | … | … | … |
| 27 years | 6.4 ± 0.5 | 6.3 ± 0.5 | 0.31 |

| **Group** | **Athletes** | **Non-athletes** | **Effect size*** |
|---|---|---|---|
| **Number** | **7** | **6** | |
| **Countermovement jump height / cm** | | | |
| 27 years | 31.6 ± 5.7 | 27.6 ± 5.0 | 0.81 |
| **Squat jump height / cm** | | | |
| 27 years | 29.9 ± 5.3 | 26.1 ± 7.2 | 0.74 |
| **Contraction time of vastus lateralis / ms** | | | |
| 9 years | 20.7 ± 2.5 | 19.2 ± 2.6 | -0.57 |
| 10 years | 19.0 ± 2.1 | 17.6 ± 2.1 | -0.64 |
| 11 years | 19.3 ± 4.2 | 19.2 ± 2.8 | -0.01 |
| 12 years | 21.7 ± 4.4 | 20.4 ± 2.3 | -0.56 |
| 13 years | 21.6 ± 3.6 | 22.1 ± 2.4 | 0.22 |
| 14 years | 22.7 ± 3.7 | 23.7 ± 3.3 | 0.30 |
| … | … | … | … |
| 27 years | 21.5 ± 3.0 | 21.4 ± 2.2 | -0.05 |
| **Contraction time of biceps femoris / ms** | | | |
| 9 years | 32.1 ± 3.5 | 34.2 ± 7.3 | 0.29 |
| 10 years | 31.2 ± 2.9 | 32.8 ± 9.1 | 0.17 |
| 11 years | 32.0 ± 3.5 | 33.9 ± 6.6 | 0.29 |
| 12 years | 31.1 ± 4.5 | 33.3 ± 8.6 | 0.26 |
| 13 years | 29.4 ± 3.7 | 36.9 ± 13.0 | 0.58 |
| 14 years | 29.6 ± 1.8 | 34.9 ± 12.8 | 0.41 |
| … | … | … | … |
| 27 years | 29.1 ± 2.8 | 33.9 ± 7.6 | 0.64 |
| **Sedentary time / min** | | | |
| 27 years | 335 ± 157 | 417 ± 147 | 0.55 |
| **Daily energy consumption / MET** | | | |
| 27 years | 4663 ± 2823 | 3346 ± 2780 | 0.47 |

*MET… metabolic equivalent; *positive values of effect size denote better results for athletes.*

Data from GPAQ showed higher daily energy consumption (MET) because of sport participation of athletes in parallel to lower daily sedentary time than in non-athletes. Even more, sedentary time at age of 27 years correlates negatively with body mass index ($r = -0.47$) and fat mass ($r = -0.59$), and positively with BF Tc at this same age ($r = 0.50$).

Additionally, the differences in certain socio-demographic factors and lifestyle characteristics between athletes and non-athletes were examined, which are shown in Table 5.

*Table 5: Comparison of some lifestyle characteristics of athletes and non-athletes*

| Group | Athletes | Non-athletes | Effect size* |
|---|---|---|---|
| N | 7 | 6 | |
| **Self-assessment of…:** | | | |
| General health status | 3.8 ± 0.6 | 4.2 ± 0.6 | 0.67 |
| Physical capability | 3.3 ±0.7 | 3.3 ±0.9 | 0.00 |
| Psychological status | 3.8 ±0.6 | 3.8 ±0.6 | 0.00 |
| General quality of life | 3.8 ±0.6 | 4.2 ±0.3 | 1.33 |
| **Eating habits** | | | |
| Breakfast | 5.7 ±0.67 | 4.0 ±1.9 | 0.89 |
| Morning snack | 3.2 ± 1.0 | 2.4 ± 1.6 | 0.50 |
| Lunch | 5.5 ±0.7 | 5.8 ±0.3 | 1.00 |
| Afternoon snack | 3.3 ± 1.6 | 2.5 ±1.0 | 0.80 |
| Dinner | 5.2 ±1.4 | 5.5 ±0.7 | 0.43 |
| **Food consumption** | | | |
| Whole-grain bread | 4.0 ± 1.2 | 4.3 ± 2.0 | 0.15 |
| Olive oil | 4.3 ± 1.3 | 5.8 ± 1.0 | 1.50 |
| Milk and low-fat dairy | 3.8 ± 1.2 | 4.8 ± 2.0 | 0.50 |
| Cottage cheese, yogurt, cheese | 4.2 ± 1.5 | 4.3 ± 2.0 | 0.05 |
| Dark chocolate | 2.3 ± 1.3 | 2.0 ± 0.9 | 0.33 |
| Meat products | 3.7 ± 1.2 | 2.0 ± 1.3 | 1.31 |
| Red meat | 2.8 ± 1.2 | 3.0 ± 1.3 | 0.15 |
| Poultry | 3.8 ± 1.2 | 2.5 ± 1.4 | 0.93 |
| Bacon | 2.0 ± 0.9 | 2.3 ± 1.2 | 0.25 |
| Fish | 2.7 ± 1.0 | 2.3 ± 0.7 | 0.57 |
| Fizzy and non-fizzy non-alcoholic drinks | 3.0 ± 1.0 | 3.8 ± 2.2 | 0.36 |
| Alcohol beverages | 2.3 ± 0.4 | 3.7 ± 0.9 | 1.56 |
| Fried dishes | 2.8 ± 1.0 | 3.3 ± 1.2 | 0.42 |

** effect sizes are presented as absolute values.*

A noticeable difference between the groups was that athletes reported predominantly standing (physical work) while non-athletes, all but one, reported predominantly sedentary work. There were no differences between athletes and non-athletes in terms of subjective assessment of physical fitness, mental well-being, and health concerns, but interestingly athletes rated their general health (effect size 0.67) and their overall quality of life (effect size 1.33) lower than did non-athletes.

Much of the difference between the groups was reflected in eating habits, with athletes eating more regularly and skipping breakfast and afternoon snack less often (effect sizes 0.89 and from 0.50 to 0.80, respectively) than non-athletes. In terms of food choices athletes are more likely to eat meat products (effect size 1.31), especially poultry (effect size 0.93). Non-athletes, on the other hand, are more likely to consume olive oil (effect size 1.50) and alcoholic beverages (effect size 1.56).

## DISCUSSION

Based on effect sizes, due to low number of participants, we could conclude that at the age of 27 years athletes had lower body mass index, fat mass, sedentary time, BF Tc and higher running speed, countermovement and squat jump heights and daily energy consumption when compared to non-athletes. Similar trends as at 27 years were also found in the age period from 9 to 14 years, but only for two abovementioned longitudinal variables: body mass index and BF Tc. Interestingly, only running speed was at 9–14 years lower in athletes than in non-athletes, the opposite as at 27 years. At the age of 27, the largest effect size was recorded for countermovement jump height, squat jump height, body mass index, and BF Tc (effect sizes > 0.60).

This is the first study to collect 18 years of longitudinal data on TMG parameters from childhood to adulthood. We have previously reported that children's regular participation in sports was associated with shorter BF Tc, but not with VL Tc, as found here. More specifically, BF Tc differences were observed between sedentary and athletic groups in boys and girls and were significant at 12 years of age (Šimunič et al., 2017). As this sample was a sub-sample of the previous study a similar result could be confirmed for the period of 9-14 years. However, this trend was maintained or even slightly increased with regular sport exercise until the age of 27 years. Although short Tc was confirmed in BF it was not the case for VL Tc, which seems to be independent from regular exercise. A similar situation was observed in adult track and field sprinters where sport participation resulted in a higher proportion of type IIc fibers in the BF, which was also associated with a lower BF Tc (19.5 vs. 30.2 ms in sprinters vs. sedentary subjects, respectively) (Dahmane, Djordjevič, & Smerdu, 2006). It could be that the habitual loading of weight-bearing muscles (as for VL) through normal daily physical activity is already relatively high in non-athletes and that the non-weight bearing muscles are more heavily loaded during exercise (Šimunič et al., 2017). If so, this may explain the grater adaptation to regular exercise in BF than in VL. Our group of athletes consisted of three handball players, two volleyball players, one dancer and one multisport athlete. When we compare their average BF Tc's at the age of 27 years (29.6 ms) with the averages of other groups of adult athletes, e.g., male sprinters at 19 ms (Šimunič et al., 2017), beach volleyball players at 25 ms (Rodríguez Ruiz et al., 2012), gymnasts at 27 ms (Šimunič et al., 2017), and football players at 28 ms (Rey, Lago-Peñas, Lago-Ballesteros, & Casáis, 2012) they have a longer BF Tc, but a shorter BF Tc than non-athletes with 32 ms (Šimunič, 2012; Šimunič, Pišot, Rittweger, & Degens, 2018). Thus it appears that participation in sports during childhood may lead to a faster profile of BF Tc, an important muscle for fast explosive sports such as football, volleyball, sprinting, and gymnastics as well as for overall knee health (Biscarini, Botti, & Pettorossi, 2013; Guelich, Xu, Koh, Nuber, & Zhang, 2016). To support this, we have previously reported that children who regularly participate in sports also have higher running speed (Volmut, Pišot, & Šimunič, 2016) and that this was negatively correlated with BF Tc (Pišot et al., 2004; Završnik et al., 2016) - but only in boys beyond the age of 13 years. And indeed, we were able to confirm higher sprinting velocity in athletes only at the age of 27 years, and not before, as five of the six participants in the non-athlete group also practiced sports during the age period of 9–14 years.

For all other non-longitudinal variables of body composition and muscle performance, which were not assessed until age 27, differences between the two groups were in favor of the athletes. Specifically, athletes had lower fat mass, which is indicative of a lower body mass index, and had higher jumping performance, an indicator of overall body strength. Regarding lifestyle variables, athletes had lower sedentary time and higher daily energy consumption. Although we have found moderately lower sedentary time in athletes, when compared to non-athletes, it is not always so, as previous studies reported that athletes can be highly active and have high sedentary time, because of an independent relationship between moderate-to-vigorous physical activity time and sitting time (Swartzendruber, Croteau, & Maine, 2020; Weiler, Aggio, Hamer, Taylor, & Kumar, 2015). The relationship among high sedentary time for athletes' health, risk of cardiovascular and metabolic diseases, despite high activity level, remains to be seen.

In their self-reporting, athletes rated their health and quality of life worse than did non-athletes. Although their health status did not reflect any serious medical condition or show any chronic diseases, we can speculate that athletes report lower QoL due to their recent injury experience as these lower scores primarily affect social and global functioning, suggesting that they feel that their injuries limit their ability to participate in sports and social life (McGuine, Winterstein, Carr, Hetzel, & Scott, 2012; Valovich McLeod, Bay, Parsons, Sauers, & Snyder, 2009). It is also evident that athletes eat more regularly, place more emphasis on breakfast, eat healthy snacks with higher intake of animal-sourced protein, and consume less fats and less alcohol. Our findings are consistent with adolescent athletes eating healthier and having more varied diets (von Rosen, Olofsson, Väsbom, & Heijne, 2019).

The major limitation of the study was the small sample number and low response rate of participants for re-testing (11 %). This is a major shortcoming of all longitudinal studies due to the EU regulation of personal data protection, disinterest of participants in attending the later measurements, and certainly in this case the COVID-19 pandemics. Furthermore, we had both sexes in both groups but of similar distribution. Therefore, we have done only effect size estimation without statistical hypothesis testing.

## CONCLUSION

Despite the small sample we can identify a trend which confirms that many years of sports participation and regular exercise have positive effects on physical fitness and motor abilities, and especially on the contractile properties of the skeletal muscles. Athletes have lower body mass index, exhibit greater running speed, better jumping performance and shorter contraction time of the posterior thigh muscle. Athletes also spent less time sitting and have higher daily energy expenditure than non-athletes, but this was not reflected on fat mass. The contraction time of the anterior thigh muscles, which did not differ between the groups, confirms our previous findings that the daily stimulus of the postural muscles is large enough to maintain contractile properties, which is not the case for the posterior thigh muscles, which are less used during daily tasks. We also found healthier lifestyle habits in athletes. They practice healthier diet regimes with more regular meals containing more protein (meat products, poultry) as well as fewer health-risk practices (smoking and alcohol consumption); regarding the self-assessed quality of life, athletes reported lower health status and general quality of life, which can be explained by the reported injuries and strict sport regimes of athletes.

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