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INVESTIGATION OF THE RELATIONSHIP BETWEEN ANTHROPOMETRIC CHARACTERISTICS AND MUSCULAR STRENGTH IN ELITE TURKISH MOUNTAIN BIKERS

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Abstract. **Aim.** The aim of this study was to investigate the relationship between anthropometric characteristics and muscular strength of Turkish elite moutain bikers. **Materials and methods.** The study group consisted of 12 Turkish elite male mountain bikers who participating in national and international cross country olimpic (XCO) mountain bike races in elite category for the last 2 years. Participants mean age was 22.4 ± 3.4 years, body height was 173.2 ± 5.18 cm, and body mass was 55.7 ± 75.2 kg. Participants body height and weigth were measured and body mass index of participants was calculated. To determine the muscular strength, one repetition maximum (1-RM) tests were performed on participants. The association between anthropometric characteristics and the muscular strength performance were determined by the Pearson correlation coefficient. **Results.** The mean of body heigth was positively correlated with 1-RM means for triceps pull-down and leg extension, body weigth was positively correlated with 1-RM means for biceps curl, triceps pull-down, shoulder press, lat pulldown, abdominal crunch, leg extension and leg curl, BMI was positively correlated with 1-RM means for shoulder press, chest press and leg curl ($p < .05$). However, mean age not correlated with 1-RM means for all exercises ($p > .05$). **Conclusions.** In conclusion, body weight and body mass index values are important parameters to be considered in evaluation of muscle strength and strength training in mountain bike riders.

Keywords: cycling, mountain biker, muscular strength, anthropometric characteristics

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ИССЛЕДОВАНИЕ СВЯЗИ МЕЖДУ АНТРОПОМЕТРИЧЕСКИМИ ХАРАКТЕРИСТИКАМИ И МЫШЕЧНОЙ СИЛОЙ У ЭЛИТНЫХ ТУРЕЦКИХ ГОРНЫХ ВЕЛОСПОРТСМЕНОВ

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Аннотация. **Цель:** целью данного исследования было изучение взаимосвязи между антропометрическими характеристиками и мышечной силой элитных горных велоспортсменов из Турции. **Материалы и методы.** Выборка исследования включала 12 велоспортсменов мужского пола из Турции, которые участвовали в национальных и международных олимпийских кроссах (XCO)

на горных велосипедах в элитной категории в течение последних 2 лет. У всех участников исследования измеряли рост и массу тела, рассчитывали индекс массы тела. Средний возраст участников составил 22,4 ± 3,4 года, средний рост – 173,2 ± 5,18 см, средняя масса тела – 55,7 ± 75,2 кг. Для оценки мышечной силы рассчитывали одноповторный максимум (1-RM). Связь между антропометрическими характеристиками и показателями мышечной силы определяли с помощью коэффициента корреляции Пирсона. **Результаты.** По результатам исследования установили положительную корреляцию между средним ростом тела и средними значениями 1-RM для тяги на трицепс и разгибания ног; положительную корреляцию массы тела со средними значениями 1-RM для сгибания рук на бицепс, тяги на трицепс, жима от плеч, верхней тяги, скручиваний, разгибания и сгибания ног; положительную корреляцию ИМТ со средним значением 1-RM для жима от плеч, жима от груди и сгибания ног ($p < 0,05$). Однако средний возраст не коррелировал со средним значением 1-RM для всех упражнений ($p > 0,05$). **Заключение.** Таким образом, масса тела и индекс массы тела являются важными параметрами, которые необходимо учитывать при оценке мышечной силы и силовых тренировок у велоспортсменов.

Ключевые слова: велоспорт, горный велоспорт, мышечная сила, антропометрические характеристики

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Introduction

Mountain biking is a transportation and recreation activity vehicle that has been increasing rapidly since the 1970s, especially in the USA and European countries. In the 1990s, mountain biking was accepted as the official racing discipline by the Union Cycling International (UCI) as a result of the great interest in sports and recreation activities for mountain bike users. In the 1996 Atlanta Summer Olympic Games, mountain bike races were included in the Olympic Games program for the first time and after that races have been held regularly. Today, mountain biking is a very popular nature sport, in which both recreative and large sports organizations are organized. There is a significant increase in the number of race organizations and participants in recent years [12, 20].

Cross country olympic (XCO) mountain bike races are held on mountainous terrains trails which has downhill, climb and sprint sections. Athletes should spend both short-term with maximal intensity and long-term with submaximal or moderate intensity efforts in competitions on elit level. Therefore, elite athletes need high level of aerobic and anaerobic endurance. Also, due to it's rugged course structure, mountain bike athletes should have highmuscular strength and bike control skills to overcome obstacles and maintain balance [11, 17, 22]. In the literature, cycling is a sport based on endurance performance and cyclists are also considered as endurance athletes [6, 30, 31]. For this reason, muscle strength and resistance training has been a neglected issue in cycling [19]. However, high level of muscle strength is required for good start, jumping over obstacles, explosive sprint and balance especially in mountain bike races [20, 32].

Literature studies indicate that both lower and upper limb muscle strength have a decisive effect on the race performance of mountain bike athletes [32]. Biomechanical analysis results show that the power and strength level of the ankle, knee and hip extensor and flexor muscles which are active in the pedaling movement are effective on [8]. On the other hand, obstacle crossings in mountain bikes, strength of arm muscles and shoulder junction are also defined as important performance parameters on racing performance [10]. In previous studies, level of muscle strength and its effects on race performance for elite athletes were clearly defined with very detailed biomechanical analyzes and physical performance tests on road and mountain bikes [26, 29, 33]. Recent studies reports that muscle strength level has a significant effect on start and finish sprint performance on road bikes [19]. However, despite the general belief that muscle strength is effective in racing performance on mountain bikes, the number of studies examining the muscle strength level of elite athletes is limited [12, 32]. In this regard, there is a need the studies about strength of elite athletes and related factors in mountain biking for literatur.

There is very little research on strength training in addition to endurance training on well-trained cyclists. Therefore, there is a need to further investigate the effect of strength along with

endurance training in elite cyclists [25]. With the improvement of maximal power in well-trained athletes, the peak torque increases in the pedal stroke, the time to reach the peak torque decreases and the pedaling characteristics can improve according to the maximum power. With this result, higher power output or increased blood flow may be allowed. Related to this, in a study on cyclists with close maximum oxygen consumption (VO_{2max}) and peak aerobic power output (W_{max}), low electromyography (EMG) activity during pedaling was reported in cyclists with high maximum strength [3]. From this point of view, the effect of high force values on the torque profile during pedal stroke in continued endurance training can help athletes to pedal more efficiently or provide economy of motion.

In cycling sport, anthropometric properties have an impact on both road and mountain bike racing performance. In general, cyclists have low body fat percentage, ectomorphic or ecto-mesomorphic somatotypes [27, 29]. The findings of current studies have shown that body mass and composition is an effective factor on racing performance. However, in some studies, it is stated that the increase in body mass has a negative effect on endurance performance [16]. On the other hand, there are findings indicating that the increase in body mass causes an increase in muscle strength after regular training in elite athletes. Both endurance and muscle strength have a decisive influence on racing performance on mountain bikes [19]. However, there is no study that demonstrates the relationship between anthropometric properties and muscle strength in mountainbikers. Therefore, determining the factors that affect the muscle strength and strength level of mountain bike riders will be very useful in terms of training practices and athlete development. Based on this idea, the aim of the research is to investigate the relationship between the anthropometric properties and muscular strength performance of Turkish elit mountainbike athlete who participate on international races.

Materials and methods

Participants. This research was carried out during the mountain bike competition season. The measurements and tests within the scope of the research were carried out in the performance laboratory of the Faculty of Sport Sciences, Suleyman Demirel University. The study group consisted of 12 male athletes who participated in the mountain bike competition in elite category and took part in the national team. As the criteria for inclusion in the research for the participants; a) Participating in national and international XCO mountainbike races in elite category for the last 2 years, b) To be an active athlete and has a license in the mountain bike discipline, c) Having regular training from the pre-season period, d) Being between the ages of 19–35, e) No history of surgery, fractures or trauma during the past six months, f) Not having any systemic and neurological problems, g) Being volunteer to participate in the research, conditions were determined. Athletes who could not have the inclusion criteria and could not participate to all of the measurements and tests, were not included to the study. The research was carried out in accordance with the ethical principles stated in the Helsinki Declaration.

Data Collection. In the research, an information form prepared by the researchers was used to obtain the demographic information of the athletes. Body heigth and weight measurements were applied to determine the basic anthropometric properties. Therefore, 1-RM test protocols were used to analyze the performance of the lower and upper limb strength. It was provided temperature 23 ± 2 °C and relative humidity 45 ± 10% by using air conditioning system in the laboratory where physical performance tests were performed.

Anthropometric Measurements. Body height and weight of the mountain bikers included in the study were measured using a SECA stadiometer and TANITA weigth scale. Their heigth and weight of participants were determined as 0.01 m and 0.01 kg in accordance with international anthropometric measurement standards. Body Mass Index (BMI) values were calculated using the [(*Body weigth (kg) / (Heigth (cm))2*] formula with height and body weight measurement results of participants.

One Repetition Maximum (1-RM) Tests. 1-RM test is a popular test protocol used in many sports disciplines to determine the level of strength of athletes for muscle groups [1, 2]. 1-RM tests are used to examine the strength level in the lower and upper extremity muscle groups which are active in pedaling and cycling control [5, 21]. Prior to 1-RM test, each participant performed a warm up protocol consisted of a cycling period for 5 minutes on a bicycle trainer followed by 1 minute rest period. After the warm up protocol, they performed 8–10 repetitions with a light load (~50% of estimated 1-RM) on each resistance machine. After this repetition period, par-

ticipants rested for 1 min and than performed one repetition with a 80% of estimated 1-RM load and the full range of motion. After each successful performance, weight increased by 5–10% until a failed attempt occurred with 3min recovery. 1-RM tests were performed by alternating between upper and lower body. In order to determine the individual 1-RM for upper and lower body, chest press, triceps, pull-down, biceps curl, lat pull down, abdominal crunch, leg extention, leg curl, leg press, seated low row and shoulder press were performed for each participant. 1-RM results were recorded in kg [28].

Data Analysis. All statistical analyses were carried out using SPSS statistic software package ver. 22.0 (IBM Corp., Armonk, NY, USA). Data are presented as means with a standard deviation (± SD) and range (minimum and maximum values). The distribution of each variable was examined with the Shapiro–Wilk Test for normality. As variances showed a normal distribution, Pearson´s correlation analysis was performed to determine whether there were correlations between anthropometric variables and muscular strength (1-RM) performance on various exercise of participants. For correlation analyses, the level of statistical significance was set at p less than 0.05.

Results

The participant's mean age was 22.42 ± 3.42 years, body height was 173.17 ± 5.18 cm, and body mass was 66.04 ± 4.82 kg. Also, mean of their BMI was 19.07 ± 1.9 kg/m^2. Anthropometric characteristics of participants are described in Table 1.

Table 2 displays the mean, minimum, maximum values and standard deviations for the 1-RM values of participants.

Table 3 demonstrates the associations between anthropometric characteristics and muscular strength (1-RM) performance on various exercise of participants. The mean of body heigth was positively correlated with 1-RM means for triceps pull-down and leg extension ($p < .05$). However, there were no relationships between body heigth and other 1-RM values ($p > .05$). The mean of body weigth was positively correlated with 1-RM means for biceps curl, triceps pull-down, shoulder press, lat pulldown, abdominal crunch, leg extension and leg curl ($p < .05$). There were no relationships between body weigth and 1-RM for chest press, leg press and seated low row ($p > .05$). The mean of BMI was positively correlated with 1-RM means for shoulder press, chest press and leg curl ($p < .05$). However, there were no relationships between BMI and other 1-RM values ($p > .05$). The mean age not correlated with 1-RM means for all exercises ($p > .05$).

Discussion

The primary purpose of this study was to examine the relationship between anthropometric characteristics (age, body weigth, height and

Table 1

Anthropometric characteristics of participants

Variables	Min	Max	Mean	SD
Age (year)	18	28	22.42	3.42
Height (cm)	159	178	173.17	5.18
Weight (kg)	55,7	75.2	66.04	4.82
BMI (kg/m^2)	20.55	23.73	22.00	3.42

Table 2

1-RM values of participants

Variables	Min	Max	Mean	SD
Biceps Curl (kg)	40	70	54.33	9.33
Triceps Pull-Down (kg)	50	75	65.41	8.97
Shoulder Press (kg)	35	55	44.17	5.97
Lat Pulldown	60	77	67.41	5.96
Chest Press (kg)	65	110	86.62	13.68
Abdominal Crunch (kg)	45	95	63.75	14.00
Leg Extention (kg)	110	160	139.58	13.56
Leg Curl (kg)	42.5	85	62.2	10.74
Leg Press (kg)	140	230	181.25	28.93
Seated Low Row (kg)	65	90	75.54	10.18

Table 3

Pearson correlation coefficient analysis of physical characteristic and muscular strength of participants

Variables		*Age*	Heigth	Weigth	BMI
Biceps Curl	*r*	.325	.391	**.504***	.321
	p	.31	.10	**.04**	.15
Triceps Pull-Down (kg)	*r*	.334	**.570***	**.535***	.130
	p	.29	**.03**	**.04**	.34
Shoulder Press (kg)	*r*	–.026	.313	**.618***	**.649***
	p	.94	.16	**.02**	**.011**
Lat Pulldown	*r*	.136	.382	**.521***	.383
	p	.67	.11	**.04**	.11
Chest Press (kg)	*r*	.130	.107	.387	**542***
	p	.69	.37	.11	**.03**
Abdominal Crunch (kg)	*r*	.135	.391	**.527***	.382
	p	.67	.10	**.04**	.11
Leg Extension (kg)	*r*	–.94	**.719****	**.769****	.343
	p	.77	**.004**	**.002**	.14
Leg Curl (kg)	*r*	–.016	.250	**.670****	**.839****
	p	.96	.22	**.009**	**.000**
Leg Press (kg)	*r*	.008	.274	.460	.418
	p	.98	.19	.07	.09
Seated Low Row (kg)	*r*	–.012	.268	.461	.440
	p	.97	.20	.07	.08

Note. * – $p < .05$, ** – $p < .01$.

BMI) and muscular strength of elite male mountain bike riders in Turkey. The present study showed a direct relationship between 1-RM values and anthropometric variables observed in this mountain bikers. Overall, body weight correlated with a greater number of 1-RM values for upper and lower extremity muscle groups. There were positive medium-strong correlation between these variables (range, 0.50–0.77). Body weight is effective on performance with the load it creates due to gravity and movement resistance in cycling. Since excess body fat and muscle mass increase the energy needed for cycling and it is not a desired physical feature in elite cyclist [29]. However, if cyclist gain muscle mass increase naturally, their cycling performance increase at optimum level. Since elite athletes have low fat percentage (8–10%), the increase in body weight and 1-RM values has positive correlation that consistent literature information [4].

Anthropometric characteristics of mountain bike XCO athletes; It has been revealed that it varies according to competition level, body composition and somatotype. Over the past two decades, several studies have been conducted to identify the physiological, biomechanical, psychological, and nutritional parameters that contribute to mountain bike performance. In a study comparing elite and sub-elite cyclists; It has been reported that elite athletes are the youngest, have lower BMI and body fat ratio, and narrower thigh muscle area. On the other hand, the weekly training times (16.1 ± 1.2; 14.0 ± 2.7) and the annual training distances (18409.1 ± 1053.8; 13970.6 ± ± 3174.5) of the elite athletes are longer than the sub-elite athletes. In addition, elite cyclists had a significantly lower endomorphic feature (1.7 ± ± 0.3; 2.1 ± 0.7) and a significantly higher ectomorphic feature (3.1 ± 0.6; 2.5 ± 0.5) compared to subelite cyclists [27]. Hamilton Lee at all., found that Australian nationally and internationally competitive cross country mountain bikers and road cyclists did not differ in age or height but mountain bikers are lighter 65.3 ± 6.5 vs 74.7 ± ± 3.8 kg, $p = 0.01$; mean ± s) and leaner (sum of seven skinfolds: 33.9 ± 5.7 vs 44.5 ± 10.8 mm) than road cyclist [9]. In this study mountain bikers' and road cyclists' absolute power output weren't significantly different (413 ± 36 vs 431 ± ± 12 $p > 0.05$), but mountain biker have significantly higher relative peak power output than road cyclists (6.3 ± 0.5 vs 5.8 ± 0.3 $p < 0.05$).

Rhaí André Arriel at all reported that, the time to exaust (TE) was significantly correlated

with body mass and fat free mass ($p < 0.05$). Although the TE did not correlate significantly with body mass index ($p > 0.05$), there was a low correlation coefficient ($r = 0.30$). No significant association between TE and body fat was found ($p > 0.05$) [24].

As reported by Fornasiero at all., there were no significiant difference at body weight, body mass index and height between 4 age group (13, 14, 15, 16 years) top levels of youth mountain bikers. At the peak power outputs 15 and 16 year groups is significiantly higher than 13 year group, but at normalized peak power output only 16 year group is significiantly higher than 13 year group. As reported in that study the absolute VO_{2max} (L/min) of 16 years old male bikers was significantly lower than in adult high level athletes (4.32 ± 0.39 vs 5.11 ± 0.46 L/min) ($P < .01$), but the normalized VO_{2max} to the body mass (mL/kg/min) was not different (72.7 ± 4.4 vs 75.9 ± 5.3 mL/kg/min) for adutlh male athletes'. In the 16 year old female goup bouth absolute and normalized maxVO_2 values were not significinatly different from adult mountain bikers [7].

When the relationship between height and 1-RM values was examined, it was observed that there was a moderate relationship between height and triceps pull-down (triceps) muscle strength, and a high relationship with heigth and leg extension (rectus femoris, vastus medialis and lateralis muscules) muscle strength. When the relationship between BMI and 1-RM muscle strength, it was determined a medium-high ($r = 65$ and 54) correlation with shoulder press and chest press and a high correlation ($r = 84$) between 1-RM values and leg curl. The effect of body size on various movement performances, as well as on various physiological functions in general has been studied for decades. Several researchers have suggested that body size variables may affect maximal strength and the ability to generate power [13, 23].

According to Jaric's meta analysis in 2002; he stated that there is a positive relationship between body size and muscle strength, and longer and heavier people produce more power. He advocated the view that this effect is more pronounced among individuals of the same height among individuals who are larger in size [13].

This result of the study is directly related to muscle diameter, and it confirms the relationship between anthropometric properties, especially muscle diameter with 1-RM. This was confirmed by another study that examined the relationship between maximum force and anthropometric properties. Many researcers stated that the maximum power values and body size indicators such as muscle cross-sectional area and body mass showed a positive correlation [13, 15, 18]. In another study, Keogh et all., they looked at the relationship between body composition and maximum force on bench press and squat movement on 42 weight athletes at elite level, they found that there was no relationship between leg-arm length and 1-RM. However, they stated that the reason for this may be the study has a heterogeneous sample and the relationship between strength and limb lengths can be obtained by using more homogeneous sample in terms of body mass and height [14]. Since our sample is homogeneous in our study, this explanation supports our finding that a positive relationship between 1-RM and height. In the same study, the relationship between fat percentage and muscle mass with 1-RM was found to be positive, and it supports the positivity of the correlation between the muscle mass and 1-RM we obtained in our study. In the related study, the relationship between the size of the skeletal muscle per cm (muscoskeletal size) and maximum weigth was also examined and the correlation value; 0.55 for bench press and 0.68 for squat. We can say that this is due to increase in muscle mass as height increases, and accordingly the kg value that muscle can lift per cm may increase.

The results of the research revealed that there was no significant relationship between the mean age of the participants (22.42 ± 3.42 years, range 18–28 year) and 1-RM values. It is known that there is a significant relationship between muscle strength and age in sports sciences. However, in adult groups, sarcopenia which is expressed as a decrease in muscle strength with age, begins to develop from the age of 30. Since the age range of our research group is 18–28 years, a sarcopenic effect cannot be mentioned, it is a reasonable result that there is no significant relationship between the average age of the research group and the 1-RM values. When the literature examples are examined, racing experience in elite mountain bike is considered as a very important performance component and it is seen that the average age in the international organizations is between 25–30. In this regard, it can be stated that the average age of Turkish mountain bike riders is lower.

Conclusion

As a result of this study examining the relationship between the anthropometric characteristics and muscle strength of elite male mountain bike cyclists; it was determined that the body weights of elite mountain bikers were particularly associated with upper extremity muscle strength, while the BMI value was associated with shoulder, trunk and leg strength. In this regard, body weight and body mass are important parameters to be considered in the evaluation of the strength performance of athletes in mountain bikes. In elite mountainbike athletes, decreasing in body weight and BMI values may be a sign of decreesing on muscle strength or increasing in body weight and BMI values may be a sign of increasing in muscle strength during regular training period. In addition, the behavior of athletes to lose weight during periods of intense training and competition may cause loss of muscle strength and a decrease in race performance. In this respect, it will be beneficial for athletic performance development in the mountain bike training applications to monitör the body weight and BMI values of the athletes regularly and make revisions to the training content according to the change.

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