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Original

COMPARACIÓN EN LOS MOTOCICLISTAS EN LA FUERZA DEL APRETÓN DE MANO Y SU TIEMPO DE REACCIÓN

COMPARISON OF MOTORCYCLISTS' HAND GRIP STRENGTH AND REACTION TIME

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RESUMEN

El propósito de este estudio fue comparar la fuerza de agarre de la mano y los tiempos de reacción en motociclistas masculinos agrupados según sus diferentes edades y clases de motocicletas utilizadas además de determinar la relación entre estas características.

Un total de 65 motociclistas varones sanos se dividieron en cuatro grupos según su edad y las diferentes clases de motocicletas: (Grupo-1 [G1] = 600-CC / 23-34 años; Grupo-2 [G2] = 600-CC / 35-48 años; Grupo-3 [G3] = 1000-CC / 23-34 años; Grupo-4 [G4] = 1000-CC / 35-48 años). El tiempo de reacción de Nelson y la fuerza máxima de agarre de la mano se midieron para ambas manos.

No hubo diferencias significativas entre los valores de fuerza de los grupos ($p > 0.05$). Se encontró que el tiempo de reacción del lado derecho e izquierdo del Grupo 1 fue más corto en el Grupo 2, y el tiempo de reacción del lado izquierdo del Grupo 1 fue más corto que el del Grupo 3 ($p < 0.05$). Se encontró que el tiempo de reacción de la mano derecha tenía una correlación negativa con la fuerza de agarre absoluta de la mano izquierda ($r = -0,247$, $p = 0,047$). Se encontró que tenía una correlación positiva con la altura ($r = 0.315$, $p = 0.011$). Los tiempos de reacción del grupo de edad joven (23-34 años) que utilizan motocicletas de motor más bajo (600-CC) son mejores.

Aunque los valores absolutos de la fuerza de agarre de la mano no difieren según de las diferentes edades y la potencia del motor utilizada, se encontró que el tiempo de reacción simple aumenta con la edad.

Palabras clave: mano fuerza, reacción tiempo, motociclista.

ABSTRACT

The purpose of this study was to compare hand grip strength and reaction times in male motorcycle racers grouped according to different ages and the classes of motorcycle used and determine the relation between these characteristics.

Sixty-five healthy male motorcycle racers were divided into four groups according to their age and the power of the motorcycles' engine: (Group-1 [G1] = 600-CC/23-34 years; Group-2 [G2] = 600-CC/35-48 years; Group-3 [G3] = 1000-CC/23-34 years; Group-4 [G4] = 1000-CC/35-48 years). Then, Nelson's reaction time and maximal hand grip strength were measured for both hands.

There were no significant differences between the groups' grip strength ($p > 0.05$). It was found that G1's right-and left-hand reaction time was faster than that of G2, and G1's left-hand reaction time was faster than that of G3 ($p < 0.05$). The right-hand visual reaction time was found to have a negative weak correlation with the left-hand absolute grip strength ($r = -0.247$, $p = 0.047$), and there was a weak positive correlation between the left-hand visual reaction time and height ($r = 0.315$, $p = 0.011$). G1's right-hand visual reaction time was better than that of G2 ($p < 0.001$), and G1's visual left-hand reaction time was better than those of G2 ($p < 0.034$) and G3 ($p < 0.011$).

Although the absolute and relative hand grip strength values did not differ according to the ages and the engine power of the motorcycle used, it was found that the simple reaction time increased with increasing age.

Keywords: hand strength, reaction time, motorcyclist

INTRODUCTION

Although motorcycling is a sport in which the individual has a high risk of injury and death (Singh et al., 2015), its popularity has increased over the years (D'Artibale et al., 2007). It has also been reported that approximately 14% of central nervous system injuries in motorcycles are mild head and / or brain injuries, in 95% of which loss of consciousness occurs (Daniels et al., 2015). Thus, in a sport such as this, in which the injury rate is high, technical skills are highly important.

Road-race motorcycle performance depends on the motorcycle's characteristics as well as the rider's abilities (Sánchez-Muñoz et al., 2011). Motorcyclists require unique performance abilities to ride various-sized motorcycles in which frequent changes of direction, forces, velocity, and acceleration are required (Bach et al., 2015). The riders also require intense neuromuscular activity to ride fast and manoeuvre the motorcycle on the track (i.e., operational movements on handlebars, foot pegs, and body positions) while counteracting the numerous acceleration forces (i.e., anterior, posterior, lateral) (D'Artibale et al., 2018). Further, motorcyclists must use the majority of their entire body musculature and both the aerobic and anaerobic energy systems, in addition to the requisite skills needed to control the motorcycle around the challenging track (Bach et al., 2015). To react rapidly to the motorcycle's vigorous and sudden movements, it is important for the rider to have developed skills, muscle strength, and endurance (Konttinen et al., 2007).

In addition to the motor's characteristics, because motorcycles are weight-regulated, a lighter and smaller rider is usually considered to have a performance advantage (D'Artibale et al., 2018). It has been stated that optimal weight distribution on the motorbike is very important (Sánchez-Muñoz et al., 2011). In addition, the road-racer's height also has an influence on performance, although less than weight. Excessive height increases the front area of the rider-motorcycle combination and therefore, the drag force results in a decrease in speed. Thus, the road-race rider's maximum height should be one that allows him to adapt behind the motorcycle fairing. On the other hand, when the rider is too small, the motorcycle's controls must be adapted to allow optimum riding (Sánchez-Muñoz et al., 2011). It has been reported that a heavier rider requires more muscular force to achieve optimal control of his motorcycle (Gobbi et al., 2005). On the other hand, although a low weight may compromise the grip on the exit of the curves, the low power of the motorcycles in this category minimizes weight's influence on grip. Despite these views, it has been emphasized that generally, a lighter rider should perform better. However, anthropometry's actual influence on optimal performance is currently unknown (D'Artibale et al., 2018). Therefore, new studies are needed to clarify this subject.

Upper limb strength is also an important factor in motorcycling (Sánchez-Muñoz et al., 2011). It has been reported that grip strength may be bilaterally equal in some sports that require the active use of both hands (Gerodimos, 2012). Because of the importance of preventing injuries in athletes, the development of general strength, grip strength profiles, and their relation to performance are set forth often (Cronin et al., 2017). While riding a motorcycle, a sustained volar grip is required to correct and stabilize both of the intensely vibrating handlebars continuously (Humpherys et al., 2018). During motocross riding, the fingers, other than those that operate the clutch and front brake lever, must grip the handlebars tightly throughout. It has been reported that there is a 16% reduction in maximal strength attributable to the competitions' long duration and fatigue in the rider's finger and wrist flexor muscles during this period (Konttinen et al., 2007). In addition, over the course of the race, braking may be needed from time to time depending upon external factors. These situations emphasize the importance of the upper extremities' strength. Gobi et al. (2005) reported significantly greater handgrip strength in the left limb of a group of motorcross racers, which was the non-dominant arm in all subjects, compared with their right limb (+6%). The authors suggested that this is attributable to the repetitive use of the clutch on a motorcross bike (Gobi et al., 2005). On the other hand, peak handgrip strength was reported to be significantly higher in the right hand, which is used to operate the brake lever and throttle, than in the left hand (used to operate the clutch lever) in female adult riders (D'Artibal et al., 2007) and, similarly, significantly higher in young elite riders (Sánchez-Muñoz et al., 2011). The authors suggested that this is attributable to the repetitive use of the clutch on a motorcross bike (D'Artibal et al., 2007; Sánchez-Muñoz et al., 2011). Nonetheless, there is no consensus on motorcyclists' bilateral differences in hand grip strength. It has been reported that these differences

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may arise from studies' different measurement methods (Bach et al., 2015).

In addition to the absolute hand grip strength, it has been suggested that the use of relative force or more complex modeling techniques may be appropriate in some cases (Sayer et al., 2007). The use of body weight to adjust muscle strength is one of the recommended methods in muscle health research (Byeon et al., 2019). Relative handgrip strength, defined as hand strength divided by body weight, is known to serve as an easy instrument to measure muscle health in public health and clinical practice. Because handgrip strength is correlated strongly with anthropometric variables and body composition (Dağ & Erdoğan, 2020), it is reasonable to hypothesize that correcting hand grip strength values with body weight may achieve more reliable results when evaluating the strength of motorcyclists of various ages and different physical characteristics. Despite this point of view, to the best of our knowledge, the absence of studies in which the grip strength in motorcycle sports, particularly absolute and relative (i.e., dividing by the athlete's body mass) values have been reported together, indicates that more research is required in this area. Further, in sports, the morphological discrepancies between the body sides also depend on the particular discipline that the athletes practice (Burdukiewicz et al., 2020).

In addition to the differences in bilateral hand grip strength, it is recognized that hypertrophic forearms appear to be a common feature of motorcyclists and depend on the form of motorcycle riding. It is thought that the more specific use of the clutch lever in off-road driving demonstrates left-hand control. Road racers extend the entire wrist frequently to keep the throttle open fully to reduce the load attributable to hard braking. Therefore, it has been emphasized that the stronger right side and the more frequent occurrence of forearm compartment syndrome in the same limb may be the result of the form of motorcycle riding (D'Artibale et al., 2018). Chronic exertional compartment syndrome of the forearms is one of the pathologies found often in motorcycle racers. This forearm syndrome begins often when riders switch to a bike with a higher horsepower (from 250 to 600-cc bikes) that requires greater forearm strength to stabilize (Humpherys et al., 2018).

Some researchers have reported that non-cognitive indicators, such as grip strength, rather than physical and mental health, are related more closely to reaction time (Choudhary et al., 2016). Simple reaction time is the time between when a stimulus is applied to a person and the beginning of the person's voluntary response to that stimulus (Magill & Anderson, 2014). In some studies, different results have been reported in which the reaction time is unrelated to athletes' performance or may have a positive relation with it (Tønnessen et al., 2013). With respect to motor sports, faster reaction time has been highlighted as a key important feature of this sport (Baur et al., 2006). This feature is important in motorcycle racers' ability to demonstrate intense neuromuscular activity (i.e., operational movements on handlebars, foot pegs, and body positions) by resisting numerous accelerations to maneuver the motorcycle and drive fast on the track (D'Artibale et al., 2018). In addition, it has been suggested that the reaction time should focus on the cause-effect relations amongst motorcycle athletes' performance levels (Tønnessen et al., 2013). Although the relation between physical, motor, and cognitive skills has been revealed in many sports (Ellison et al., 2014), it is noteworthy that the relation between reaction time and hand grip strength has not been studied adequately in motorcyclists, where races are held all over the world and the vehicle's use in daily life is increasing rapidly. Studies on this subject are important, as they can be used to develop a training strategy to understand the sports-specific physical fitness profiles of contestant-level motorcyclists better, increase their performance and importantly, prevent their injury.

In light of the information available, this study was designed to determine the profile of bilateral hand grip strength and visual reaction times in elite male motorcycle racers, as well as the potential relations between these characteristics. The second goal of our study was to compare both of these characteristics in groups with different ages who use motorcycles with different engine powers. The study's third goal was to determine the correlation between anthropometric characteristics, bilateral hand grip strength, and visual reaction times.

MATERIALS AND METHODS

Participants

The study population consisted of 65 elite male motorcyclist volunteers whose ages ranged from 23 to 48 (mean: 34.48 ± 5.99 years. All participants were athletes who had been licensed for at least three years.

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The study included athletes (1) between the ages of 23 and 48; (2) who were listed on the Turkish Motorcycle Federation Racer List, and (3) who had no lower or upper extremity injuries at least three months before the study began. Key demographic information, dominant hand, driving experiences, and brief medical histories were collected from each participant through a questionnaire. The dominant hand was described as the hand of choice for daily activities, such as writing and eating and carrying heavy objects (Mitsionis et al., 2009). All participants were right-handed. The participants were divided into four groups according to their age, and the class of motorcycles they use (Group-1 [G1] = 600-CC/23-34 years; Group-2 [G2] = 600-CC/35-48 years; Group-3 [G3] = 1000-CC/23-34 years, and Group-4 [G4] = 1000-CC/35-48 years).

All participants were informed about the study's purpose and procedure, and provided written informed consent at the beginning of the study. The study began after approval was obtained from the Health Committee of the Motorcycle Federation of the country.

Design

The study adopted a cross-sectional, descriptive, and comparative design. All tests were conducted between 10:00 and 17:00 hours before the competitions under the same conditions on the day of the Turkish Track Championships. Each participant completed the tests within one day. On the day of the test, anthropometric measurements of the participants were taken, followed by right-left hand reaction time and right-left hand maximal isometric grip strength tests, respectively. The reaction time was tested before other measurements, as it included coordination, strength, and condition-related properties. A one-minute rest was allowed between each test for the same extremity, and the test transitions between the right and left extremities were performed alternately. The 65 athletes were assigned to the tests randomly. The beginning hand (left or right) was selected randomly as well to avoid any order effect. Participants had been informed about all experimental tests before the initial performance to acquaint them with the process. The participants were asked not to engage in any challenging exercise 24 hours before the tests, and to avoid consuming food or drinking any liquid within at least three hours before the measurements. They were also advised to avoid ingesting caffeine or other stimulants.

Outcome measures

Anthropometric measures

The participants' height and body weight were measured in shorts and T-shirts without shoes. Height was measured using a portable stadiometer (Seca Stadiometer 222; Seca Instruments Ltd., Hamburg, Germany) with an accuracy of 1 mm and body weight was measured with a digital scale with a precision of 0.05 kg (WB-110A, Tanita, Tokyo, Japan). The body mass index (BMI) was also calculated (BMI = body weight (kg) / length of height (m^2).

Upper extremity reaction time test

The reaction time is the time between a stimulus's onset and the beginning of the motor response, and is measured with the Nelson Reaction Test, referred to also as the Ruler drop test (Aranha & Samuel, 2015). Designed to test the speed of movement and response accuracy, this method is reported to have a high reliability coefficient of 0.86-0.89 in measuring the hands' reaction time (Salehzadeh & Ghorbanzadeh, 2015). Participants performed the test in a quiet and sufficiently lighted environment where they were able to perform it in a concentrated manner. A 30 cm long and marked ruler was used for the test (Anitha & Samuel, 2018). Each subject placed his forearm and hand on the table conveniently, holding his thumb and forefinger 5 cm apart in the horizontal plane. The participant was asked to keep the tips of the thumb and index fingers parallel to each other and 8-10 cm from the table. While the test manager held the ruler at the far end (point 0) between the participant's fingers, s/he asked the person to look at the middle of the ruler. When the participant was ready, the ruler was released vertically from above to below, and the person was told to grasp the ruler as soon as possible with his hand and index finger. All participants were given five practices and a 30-second rest period between each. After deleting the best and worst values, the means of the three remaining measurements were recorded in cm, and the participants' reaction times (seconds) were calculated according to the following formula (Anitha & Samuel, 2018).

Reaction time =

$$\sqrt{2 \text{ x distance the ruler falls / velocity due to gravity}}$$

The formula for the Nelson Reaction Timescale (ruler) used is = $\sqrt{2 \text{ x distance (m) / 9,81 m / s2}}$

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Hand grip strength measurements

To obtain grip strength measurements, the participants' position was standardized and described in detail per the recommendations of the American Society of Hand Therapists (Roberts et al., 2011). Appropriate positioning was made to avoid compensatory movements and all verbal directions were standardized and then implemented (Coelho de Morais, 2013). All measurements were performed randomly for both the dominant and non-dominant hand. The portable Jamar hydraulic hand dynamometer (Sammons Preston, Rolyan, Bolingbrook, IL, USA), the hand grip strength of which previous research has determined to be high (r = 0.973) was used and measured in kg (Chang et al., 2010). The dynamometer was calibrated before the first measurement. The grip lever of the dynamometer was adjusted to each athlete's hand length to achieve an optimum grip position (Zafar et al., 2018). Participants were asked to sit in a comfortable position with their feet on the floor and grasp the hand dynamometer as they began the test. The grip strength measurement was performed while the elbow was flexed 90^0, the forearm was in the neutral position, and the wrist was in 0-30^0 dorsiflexion (Roberts et al., 2011). During the measurement, participants were asked to squeeze the dynamometer as hard as possible without moving other parts of the body, and then hold the position for 3 seconds. The values were read from the dynamometer scale in kg when the needle did not move after maximum muscle contraction (Dhara, et al., 2009). Previous studies have reported that the time required to reach maximum force was less than 2 seconds (Kamimura & Ikuta, 2001); instead, 3 seconds was adopted for the contraction time in this study, as Yamauchi and Hargens (2008) emphasized that 3 seconds is better to achieve the best value. The measurement was performed for both sides alternately. A 1-minute break was taken between exercises and the measurement was taken three times (Franchini et al., 2018). This rest period was used because it constitutes a sufficient break to relieve fatigue from the previous test (Kamimura & Ikuta, 2001). The grip strength was measured three times on the dominant (right-hand) and non-dominant (left-hand) sides randomly and the means were recorded. In addition to the absolute hand grip strength values determined bilaterally, the relative hand grip strength: Fmax (kgf) / body mass (kg)] strength value was also calculated (Franchini et al., 2018).

Statistical analysis

Descriptive statistics (mean, standard deviation, minimum, maximum) were employed in the study. According to the Shapiro–Wilk test, most parameter values had a nonnormal distribution. Therefore, the Kruskal–Wallis test was performed for each variable to establish statistically significant differences in values obtained from the three groups ($p < 0.05$). The Mann–Whitney U test was used as a post hoc test to determine the difference between individual pairs of groups. The relations between the variables were evaluated using Spearman (r) correlation analysis. SPSS v. 22.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for data analysis. $p < 0.05$ was considered significant in this study.

RESULTS

The participants were divided into four groups according to their age and motorcycle class (Group-1 [G1] = 600-CC/23-34 years; Group-2 [G2] = 600-CC/35-48 years; Group-3 [G3] = 1000-CC/23-34 years; Group-4 [G4] = 1000-CC/35-48 years) and are presented in Table 1. The results of the analyses were made per the engine power and age grouping; in both motorcycle classifications (600-CC, 1000-CC), there was a statistical difference between the ages of the participants in the 23-34 and 35-48 age group (G1<G2; G1<G4; G3<G2; G3<G4; $p < 0.001$).

No statistically significant differences were found between the participants in the four groups in height, body weight, and BMI (Table 1). Table 2 demonstrates cross-group comparisons of participants with right- and left-hand grip strength and reaction times. The analysis showed that G1's (600-CC engine power / 23-34 years) right- and left-hand reaction time was lower than that of G2 (600-CC engine power / 35-48 years) (Table 2). Moreover, G1's (600-CC engine power/ 23-34 years) left-hand reaction time was also lower than that of G3 (1000-CC engine power / 23-34 years) (Table 2). The within-group comparisons (Table 3) showed that there were no statistically significant bilateral differences between each of the right-left hand absolute strength, right-left hand relative grip, and right-left hand reaction time test values ($p > 0.05$) in athletes aged 23-34 who use a 600-CC engine. Similar results were also found for athletes aged 35-48 who use 600-CC engines ($p > 0.05$).

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Table-1. Anthropometric variables for the motorcycle riders by age (years) and motorcycle group

Variables	All group (n= 65)	600-CC Groups G1 – 600-CC/ 23-34 Years (n= 18)	600-CC Groups G2 – 600-CC/ 35-48 Years (n= 14)	1000-CC Groups G3 – 1000-CC/ 23-34 Years (n= 14)	1000-CC Groups G4 – 1000-CC/ 35-48 Years (n= 19)	${}^{a}p$
Age (year)	34.48 ± 5.99 (23 – 48)	29.28 ± 3.25[b,c] (23 – 34)	37.86 ± 3.26 [d,e] (35 – 45)	30.07 ± 2.27 (26 – 34)	40.16 ± 4.60 (35 – 48)	0.001*
Body height (cm)	176.84 ± 4.85 (167 – 188)	175.06 ± 5.02 (167 – 185)	176.71 ± 4.77 (167 – 183)	178.86 ± 4.94 (167 – 187)	177.16 ± 4.38 (170 – 188)	0.218
Body weight (kg)	78. 88 ± 5.04 (62 – 92)	78.28 ± 6.86 (62 – 92)	77.93± 3.88 (72 – 86)	78.74 ± 3.70 (72 – 86)	80.26 ± 4.68 (74 – 90)	0.502
BMI (kg/m^2)	25.22 ± 1.27 (22.23 – 27.93)	25.53 ± 1.75 (22.23 – 27.93)	24.97 ± 1.31 (23.22 – 26.88)	24.62 ± 0.69 (23.38 – 25.82)	25.56 ± 1.03 (24.13 – 27.78)	0.071

Values are presented as mean ± standard deviation and (minimum – máximum).

* Indicates a statistical significance; [a] Kruskal Wallis Test;

[b], [c], [d] and [e] indicate significant differences (Mann Whitney U test) between [b]G1 and G2 (G1<G2; p < 0.001), [c]G1 and G4 (G1<G4; p < 0.001),), [d]G2 and G3 (G3<G2; p < 0.001),), [e]G3 and G4 (G3<G4; p < 0.001)

Table-2. Comparation of hand grip strength, hand grip strength/Body weight and reaction time values of participants among groups.

Variables	All group (n = 65)	G1 – 600-CC/ 23-34 Years (n= 18)	G2 – 600-CC/ 35-48 Years (n= 14)	G3 – 1000-CC/ 23-34 Years (n =14)	G4 – 1000-CC/ 35-48 Years (n= 19)	${}^{a}p$
Right hand grip strength (kgf)	45.74 ± 7.42 (20.41 – 64.11)	43.75 ± 7.16 (27.22 – 54.73)	47.94 ± 5.97 (33.87 – 58.06)	48.86 ± 6.23 (35.38 – 56.25)	45.18- ± 6.69 (36.59 – 64.11)	0.105
Right hand grip strength/Body weight (kgf/kg)	0.58 ± 0.11 (0.27 – 0.79)	0.57 ± 0.12 (0.32 – 0.79)	0.62 ± 0.09 (0.45 – 0.78)	0.62 ± 0.09 (0.43 – 0.73)	0.56 ± 0.09 (0.43 – 0.71)	0.214
Right hand reaction times (s)	0.15 ± 0.16 (0.12 – 0.21)	0.14 ± 0.01[b] (0.12 – 0.16)	0.16 ± 0.02 (0.14 – 0.21)	0.16 ± 0.02 (0.13 – 0.19)	0.15 ± 0.01 (0.13 – 0.18)	0.022*
Left hand grip strength (kgf)	44.36 ± 7.41 (19.65 – 61.23)	44.57 ± 7.62 (28.58 – 61.23)	46.32 ± 5.12 (38.41 – 55.64)	46.10 ± 7.48 (33.11 – 59.27)	42.84 ± 6.52 (34.17 – 60.48)	0.233
Left hand grip strength/Body weight (kgf/kg)	0.57 ± 0.11 (0.26 – 0.88)	0.58 ± 0.13 (0.34 – 0.88)	0.60 ± 0.08 (0.46 – 0.74)	0.59 ± 0.10 (0.40 – 0.74)	0.53 ± 0.08 (0.40 – 0.67)	0.180
Left hand reaction times (s)	0.15 ± 0.15 (0.11 – 0.18)	0.14 ± 0.01[c,d] (0.12 – 0.16)	0.15 ± 0.01 (0.12 – 0.18)	0.16 ± 0.01 (0.14 – 0.18)	0.15 ± 0.02 (0.11 – 0.17)	0.035*

Values are presented as mean ± standard deviation and (minimum – máximum).

* Indicates a statistical significance; [a] Kruskal Wallis Test;

[b], [c] and [d] indicate significant differences (Mann Whitney U test) between [b]G1 and G2 (G1<G2; p < 0.001), [c]G1 and G2 (G1<G2; p < 0.034), [d]G1 and G3 (G1<G3; p < 0.011)

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Table 3.- The results of p values for bilateral differences within groups for hand grip strength, hand grip strength/Body weight and reaction time values.

Groups	Right- Left hand grip strength (kgf) (p values)	Right -Left hand grip strength/Body weight (kgf/kg) (p values)	Right-Left hand reaction times (s) (p values)
G1 - 600 CC / 23-34 Years (n=18)	0.879	0.811	0.836
G2 - 600 CC / 35-48 Years (n=14)	0.074	0.084	0.294
G3 - 1000 CC / 23-34 Years (n=14)	0.009**	0.009**	0.844
G4 - 1000 CC / 35-48 Years (n=19)	0.013*	0.013*	0.053
All group (n=65)	0.001	0.001	0.051

* Indicates a statistical significance Mann Whitney U Test ($p < 0.05$).

** Indicates a statistical significance Mann Whitney U Test ($p < 0.01$).

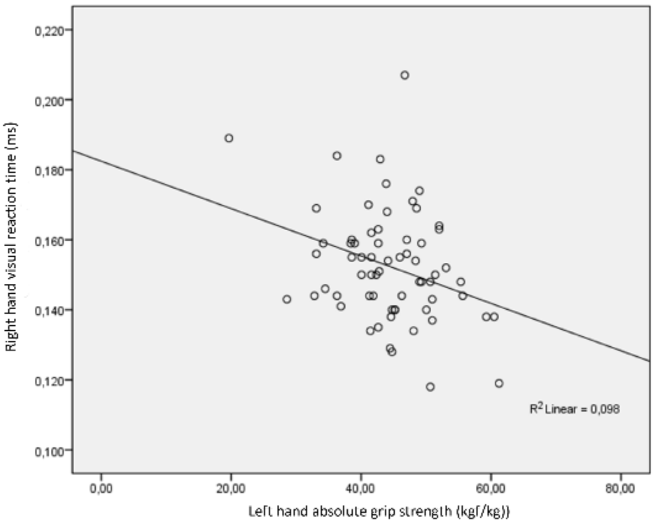

Figure-1. Correlation analyses of left-hand absolute grip strength and right-hand reaction time

According to the within-group analysis of athletes in both age groups (23-34 and 35-48 years) who use a 1000-CC engine, there was a statistically significant bilateral difference ($p < 0.05$) in the parameters of right-left hand absolute grip strength and right-left hand relative grip strength; there was no statistically significant difference between right- and left-hand reaction time values ($p > 0.05$). The strength values of the dominant hand (right) were also found to be higher in athletes in both groups (23-34 years old and 35-48 years old) who use 1000-CC motorcycles.

The assessment at the whole group level (Table 3) showed that there was a statistically significant difference between right- and left-hand absolute grip strength ($p < 0.05$). Similar differences were also found between right-left-hand relative grip strength ($p < 0.05$). In both parameters, the right-hand grip strength was found to be stronger than that of the left. There was no statistically significant difference between right- and left-hand reaction time ($p > 0.05$)

There was a weak negative correlation between right-hand visual reaction time and left-hand absolute grip strength (r = -0.247, $p = 0.047$; Table 4, Figure 1). There was also a weak positive correlation (r = 0.315, $p = 0.011$) between body height and left-hand visual reaction time. There was a positive correlation between right-hand grip and left-hand grip strength (r = 0.771, $p = 0.001$). There was also a positive correlation between right-hand relative strength and *a)* right hand grip strength (r = 0.930, $p = 0.001$), *b)* left-hand grip strength (r = 0.754, $p = 0.001$), and *c)* left-hand relative grip strength (r = 0.833, $p = 0.001$), and finally between right- and left-hand visual reaction times (r = 0.557, $p = 0.001$) (Table 4).

DISCUSSION

This study's goal was to determine and compare the profile of bilateral hand grip strength and visual reaction times in elite male motorcycle racers according to groups of different ages and the engine power of the motorcycle used. Another goal of the study was to reveal the correlation between anthropometric characteristics, bilateral hand grip strength, and visual reaction times.

The primary result of this study was that there were no statistically significant differences between both the groups' absolute and relative hand grip strength. The results showed that G1's (600 CC / 23-34 years) right- and left-hand visual reaction time was faster than that of G2 (600 CC / 35-48 years), and G1's left-hand reaction time was faster than that of G3 (1000 CC / 23-34 years). The right-hand visual reaction time was found to have a weak negative correlation between the test data of the Nelson right hand visual reaction time and left-hand grip strength. Further, a weak positive correlation was found between the left-hand visual reaction time and height.

Upper limb strength is an important factor in motorcycling (Sánchez-Muñoz et al., 2011), and one of the methods used to evaluate this characteristic is to test the handgrip strength. The grip strength is considered one of the important factors in performance in various sports (Honorato et al., 2020). Therefore, we evaluated hand grip strength, which provides objective information

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about muscle strength and is a highly reliable test, in our study. When the groups were compared according to their age and the motorcycle's engine power, both absolute and relative hand grip strength values were shown to have a similar profile. Our participants' right- and left-hand absolute grip strengths were lower than the normative data of the 20-34 (right-hand 54.79-55.25 kgf, left-hand 47.40-50.12 kgf) and 35-48 (right-hand 49.85-54.30 kgf, left-hand 45.72-52.17 kgf) age groups, which were taken in the literature in this test position (https://www.performancehealth.com/amfile/file/ download/file_id/6971/product_id/27106/). Gobbi et al. (2005) also reported the values of the absolute hand grip strengths in motorcycle racers with an average age of 25-32 while the arm is next to the body with 900 elbow flexion, and according to race categories, including Motocross (right-hand: 52.11 kgf; left-hand: 55.58 kgf), Enduro (right-hand: 51.60 kgf; left-hand: 51.60 kgf), and Desert rally (right-hand: 50.99 kgf; left-hand: 50.88kgf). It is noteworthy that our absolute hand grip strength data were lower than those in Gobbi et al. (2005) compared to motorcyclists in different race categories.

Table 4. Correlation of between demographic features hand grip strength and reaction times

		HEIGHT	RHGS	RHGS/BW	RHRT	LHGS	LHGS/BW	LHRT
HEIGHT	*r*							0.315*
	p							**0.011**
RHGS	*r*			0.930**		0.771**	0.752**	
	p		.	**0.001**		**0.001**	**0.001**	
RHGS/BW	*r*		0.930**			**0.754****	0.833	
	p		**0.001**			**0.001**	**0.001**	
RHRT	*r*					-0.247*		0.557**
	p					**0.047**		**0.001**
LHGS	*r*		0.771**	**0.754****			**0.950****	
	p		**0.001**	**0.001**			**0.001**	
LHGS/BW	*r*			0.833	0.752**	**0.950****		
	p			**0.001**	**0.001**	**0.001**		
LHRT	*r*	0.315*			0.557**			
	p	**0.011**			**0.001**			.

*Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

RHGS: RIGHT HAND GRIP STRENGHT; RHGS/BW: RIGHT HAND GRIP STRENGHT/ BODY WEIGHT; RHRT: RIGHT HAND REACTION TIME; LHGS: LEFT HAND GRIP STRENGHT; LHGS/BW: LEFT HAND GRIP STRENGHT/ BODY WEIGHT
LHRT: LEFT HAND REACTION TIME.

This difference can be regarded as an indication of our athletes' lack of absolute hand grip strength. The differences in the results may stem from the research 7 model, as well as the age, ethnicity, body structure, hand size, training levels, activities used in the training and race categories (Fanchini et al., 2018; Honorato et al. 2020; Wagh et al., 2017).

On the other hand, because of the absence of any studies on motorcycle racers in the literature that have tested the relative hand grip strength to our knowledge, a one-to-one comparison of the results of this study could not be made.

Various studies have emphasized that the fitness level achieved in physical training can also increase motorcyclists' performance in road races (Rodríguez-Pérez et al., 2019). Further, it has been reported that attention should be given to the training of hand grip strength in sports in which the grip is highly important (Iermakov et al., 2016). Hence, we recommend that motorcycle racers of different age groups incorporate bilateral exercises into their training programmes that develop their flexor and extensor muscle groups further to improve their hand grip strength effectively. This approach is important, as physical fitness is a key factor in preventing race drivers from sustaining musculoskeletal injuries (Baur et al., 2006).

It has also been emphasized that motorcycle racers' lack of grip strength is an important component for controlling the motorcycle, as it can lead to early fatigue, and increased risk of accidents and trauma (Gobi et al., 2005). The authors reported that the non-dominant left-hand grip strengths of motocross racers are higher than the right (6%). These differences can be explained by the fact that the grip strength may change depending upon the model of the engine and the ground surface of the competition (uneven, natural, road), and also by the fact that motocross racers use their left hand more when they use the clutch (D'Artibale et al., 2007).

Another finding revealed in this study was in the comparison of the differences in each group's right- and left-hand grip strength. On the one hand, we found that right-hand grip strength (absolute and relative) were higher compared to the left in racers who use 1000-CC engines. Our findings are consistent with those in Rodriguez Perez et al.'s (2019) study conducted with road-race motorcyclists. This can be explained by the fact that motorcycle racers use the brake on the right side more than the clutch the left hand controls during the competition (D'Artibale et al., 2007). Our study also showed that, in comparisons between groups, dominant right-hand grip strengths (absolute and relative) of motorcycle users in the 1000-CC 23-34 years and 1000-CC 35-48 years groups were higher compared to the left hand. It is noteworthy that the difference in the bilateral hand grip strength is attributable to the engine power, not age. More force is required to control a sudden movement that may occur in vehicles with high engine power. The adjustment of the throttle reaction in motorcycles with a large engine is of great importance to prevent sudden slippage. Therefore, wrist sensitivity can be considered one of the important components to control the right panel with the brake and the gas to control the handlebars. This study supported that view, in that the participants who use 1000-CC motorcycles had a bilateral difference in both the absolute and relative force values, while the participants who use 600-CC motorcycles did not differ. Cronin et al. (2017) reported that the isometric grip strength was higher in the dominant hand than the other (mean difference of 0.1% to 16.5%) in a compilation study they conducted with athletes, but Bohannon (2003) reported that this percentage may be lower (0.1% to 10.7%). Consistent with this information, the differences obtained between right- and left-hand grip strength in motorcycle racers have low percentage values. This can be considered an indication that the bilateral strength disparity in the upper extremities was not significant in the athletes who participated in our research.

To achieve success in sports, athletes are expected to perform at a high level with respect to their physiological and motor characteristics. Sports entail high activation of the visuomotor system, particularly those that require processing dynamic visual information (Zwierko et al., 2014). Simple reaction time is related closely to human nerve and muscle functions (Kubota and Demura, 2011) and is considered an important variable that can affect performance in motor sports (Baur et al., 2006), as well as other reaction times in other various sports (Aranha & Samuel, 2015). According to this approach, it was determined that the athletes' left- and right-hand reaction times were similar in the evaluation conducted on the entire group, but the reaction times changed bilaterally according to age group and engine power used. Reaction times vary according to age, training status, and level of central and environmental fatigue (Cojocariu, 2011).

Longitudinal research studies have reported that the rate of reaction time increases until approximately 34 years old, after which it slows between the ages of 45-54, and decreases after 65 (Deary & Der, 2005). In this study, the time measured for the right and left hand in the Nelson reaction test of the athletes in the 23-34 age group who use motorcycles with 600-CC engines compared to the participants in the 35-48 age group supports the view that the reaction time increases with increasing age (Deary & Der, 2005). In addition, this research showed that the left-hand reaction time of athletes aged 23-34 who ride motorcycles with 600-CC engines was faster than those of the same age who ride motorcycles with 1000-CC engines. This result shows that engine power of the motorcycle used, in addition to age, also affects the reaction time, particularly for the non-dominant hand. This result indicates that using a motorcycle with a lower engine power at a young age may contribute to a faster reaction time and thus, to the motorcycle's dominance. This result can be particularly advantageous in the display of intense neuromuscular activity (i.e., operational movements on handlebars, foot pegs, and body positions) when resisting multiple accelerations to make maneuvers and drive fast on the track (D'Artibale et al., 2018). However, testing the simple reaction time that is performed actively during motorcycle riding can provide this view more clearly.

One of the results of this study is the weak negative correlation between left-hand grip strength and right-hand reaction times. This result shows that the simple

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reaction time decreases with the increase in grip strength. Further, the evaluation according to different ages and engine powers showed that there was a statistically significant difference between the right- and left-hand reaction times of the participants between the ages of 23-34 and 35-48 who use 600-CC motorcycles, as well as between the left-hand reaction times of athletes who use 600-CC and 1000-CC motorcycles in the 23-34 age group. According to these findings, although the hand grip strength values were similar, the reaction times of motorcycle racers in the younger age group (23-34 years) who use motorcycles with a lower power motor (600-CC) were faster.

This result shows that the dominant hand's (right hand) reaction time might be shortened as the non-dominant hand gains strength. The shorter visual reaction time value is a significant indicator that the racers' reaction time is improving. On the other hand, there was no association between left hand grip strength and left-hand reaction time.

While riding a motorcyle, the right hand is used to operate the brake lever and throttle and the left hand is used to operate the clutch lever. During a sudden movement, both arms, which are held parallel to the ground while the right hand is pressing the brake, are extended. Thus, a bilateral force is applied to the handlebars. While the generation of force during this maneuver is observed in both arms, an enhanced reaction time is expected to be displayed for the right hand to provide additional brake control. In our research results, the negative relation between right-hand reaction time and left-hand grip strength may be related to this.

Most researchers who study reaction time suggest that an individual's ability to respond quickly to a stimulus is related largely to the nervous and muscular systems (Tønnessen et al., 2013). It has been reported that neuromuscular condition may be a factor in the positive relation between athletes' reaction time, vertical jump height, and sprint performance (Smirniotou et al., 2008). The results of our study are also consistent with those in studies that reported that non-cognitive indicators, such as hand grip strength, are related more closely to reaction time (Choudhary et al., 2016). This relation between strength and reaction time is important, as it supports the view that the combined use of the lower and upper extremities in motor sports requires a coordinated skill that is expected to be within well-structured sensorimotor control (Baur et al., 2006).

While the anthropometric data in this study had strong positive correlations among themselves, we found no relation between hand grip strength and anthropometric measurements (height, body weight, and BMI). Although similar results have been observed in adults (Kaya et al., 2005; Mitsionis et al., 2009) in studies similar to ours, various other studies have found a positive relation between BMI and hand grip strength (Massy-Westropp et al., 2011). Because different anthropometric measurements, such as shoulder width, chest and arms' circumference, and arms' length, can also be factors that affect hand grip strength, the aforementioned measures should be evaluated in future studies.

Another interesting result found in the research was that an increase in height was associated with an increase in the reaction time of the non-dominant (left) side. Unlike our research results, Tønnessen et al. (2013) reported that there is no relation between height and reaction time in male and female elite sprinters who participate in the World Athletics Championships. Samaras (2007) hypothesized that taller athletes may have a slower reaction time than shorter athletes with the same physiological characteristics because of the distance that nerve conduction must travel. To comprehend the relation between height and reaction time better, it may be appropriate to carry out different research on this in the future.

This study has various limitations. First, the small number of participants and the fact that among all physical characteristics, only height, body weight, and BMI's effects were examined, constitute limitations of this research. Moreover, the fact that comprehensive information on the athletes' background and history of injuries could not be obtained in the study can be considered a limitation as well. Further, our results reflect Turkish male motorcyclists' profiles alone. Hence, our research should be considered a pilot study and future research should include a larger sample size to investigate the motor performance of athletes in different motor sports.

CONCLUSION

In conclusion, this is the first research to determine the relation between grip strength and reaction time in Turkish male motorcyclists by grouping them according to age and motorcycle engine power. Although the hand grip strength values did not differ according to the ages and the engine power used, our study found that the simple reaction time increased with increasing age. The results showed that younger athletes (23-34 years old) who use motorcycles with lower engine power (600-CC) display better reaction time performance. It was also found that the simple reaction time decreased with an increase in right-hand absolute grip strength. We concluded that in selecting the motorcycle to use according to engine power, the reaction time and particularly, the absolute grip strength values, should be taken into consideration.

Given our results, we believe that it may be useful for motorcycle racers to include the factors of enhancing grip strength and reaction speed in their training. Although the sample size of participants was not large, the results of our study provided the bilateral grip strength (absolute and relative) and simple reaction speed profiles of male motorcycle racers between the ages of 18-46 in. These research data may be useful for sports professionals, athletes, physiotherapists, and healthcare professionals who serve in this field as a reference to reduce the risk of injury in their future studies. Further, the analysis of the relation between performance and different motor aspects in accordance with the time and training components (training duration, intensity) may be a subject for future studies.

This study revealed that the relation between reaction time, absolute grip strength, and height should be taken into account in practical applications, evaluations, and training for motorcycle racers. In practice, including evaluations of handgrip strength and reaction times in medical screenings may help identify motorcycle riders' fitness level.

CONFLICT OF INTEREST

All authors disclose that there are no financial or other conflicts of interest in the study.

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