

# Age-related Differences in Grip Strength Laterality in Male Elite Soft-tennis Players

Takahashi Kenji<sup>1,\*</sup>, Shin-ichi Demura<sup>2</sup>

<sup>1</sup>Aichi Gakusen University, Japan

<sup>2</sup>Kanazawa University, Japan

\*Corresponding author: yukkesuki.kenji@gmail.com

**Abstract** This study aimed to compare the grip strengths and laterality of dominant and non-dominant hands with respect to age among 468 male elite soft-tennis players who participated in a national athletic meet in Japan. The players ranged in age from 12 to 29 years and were classified into 12 groups according to age, with players older than 23 years old comprising a single group. Grip strength was measured twice in both hands, and the larger value for each hand was used as the representative value. We evaluated the difference in grip strength between the dominant and non-dominant hands as a variable. Statistical analysis identified significant differences between the 12-year-old group and all age groups over 14 years, and between the 13-year-old group and all age groups over 15 years. In addition, small differences were observed among age groups over 14 years. In conclusion, among male elite soft-tennis players who had participated in technical tennis training since childhood, grip strength laterality became remarkable at ages older than 14 years but generally remained constant at ages older than 17 years.

**Keywords:** upper limb strength, dynamometer, competitive racket sports

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## 1. Introduction

In Japan, the sport of soft-tennis is associated with a registered population of approximately 45 million and an estimated 700 million enthusiasts [1]. This sport is also the first competition club activity available in junior high school [2]. Players in competitive racket-based sports, which include soft-tennis as well as lawn-tennis, table-tennis, and badminton, exhibit marked laterality in upper limb strength due to frequent use of the arm/hand to maneuver the racket. Miura et al. [3] and Lucki and Nicolay [4] reported that differences between dominant and non-dominant hands in elbow flexion strength, muscle cross-sectional area, and grip strength were greater in tennis players than in the general population.

Morimoto et al. [5] further reported that a leg length discrepancy leads to posture distortion, with lower placement of the right (left) shoulder if the right (left) leg is longer than the left (right) leg. In addition, people with a larger leg length discrepancy have higher risks of disorders such as headache, stiff neck, low back pain, knee pain, and foot pain. Sports, such as soft-tennis, frequently requiring the one-sided use of upper limbs cause greater laterality in the upper limb strength of players and have also been associated with distorted body alignment. Hence, adjustments that would avoid excessive differences in upper limb muscle strength are desired.

Grip strength is representative of upper limb strength,

can be measured simply, and has a very high reliability [6]. In an earlier study, Luis et al. [7] examined grip strength differences between the dominant and non-dominant hands of junior elite table-tennis players (12 years old). Furthermore, Kubota et al. [8,9] examined the laterality of controlled forced grip strength exertion in a general population. Therefore, grip strength is considered adequate and effective for evaluating the laterality of upper limb strength.

Although grip strength laterality exists in individuals from general populations [8,10], soft-tennis players are assumed to exhibit greater grip strength laterality because they frequently use the dominant hand to manipulate a racket during practice and training. In addition, soft-tennis players participating in national competitive meets are expected to participate in long-term skill practice and technical training, leading to marked grip strength laterality that is more remarkable in older players with increased athletic experience. According to the Japan Soft-Tennis Association, the measured grip strengths in the dominant vs. non-dominant hands of male elite soft-tennis players belonging to the National, Under 20 age, Under 17 age, and Under 14 age teams were 49.1 kg vs. 38.0 kg, 47.7 kg vs. 37.5 kg, 45.2 kg vs. 35.4 kg, and 31.8 kg vs. 25.5 kg, respectively. Although these differences in grip strength are remarkable, the grip strengths of both hands and degrees of laterality have not been examined with respect to age. Accordingly, this study aimed to compare the grip strengths of the dominant and non-dominant hands and laterality according to age among male elite soft-tennis players.

## 2. Method

### 2.1. Participants

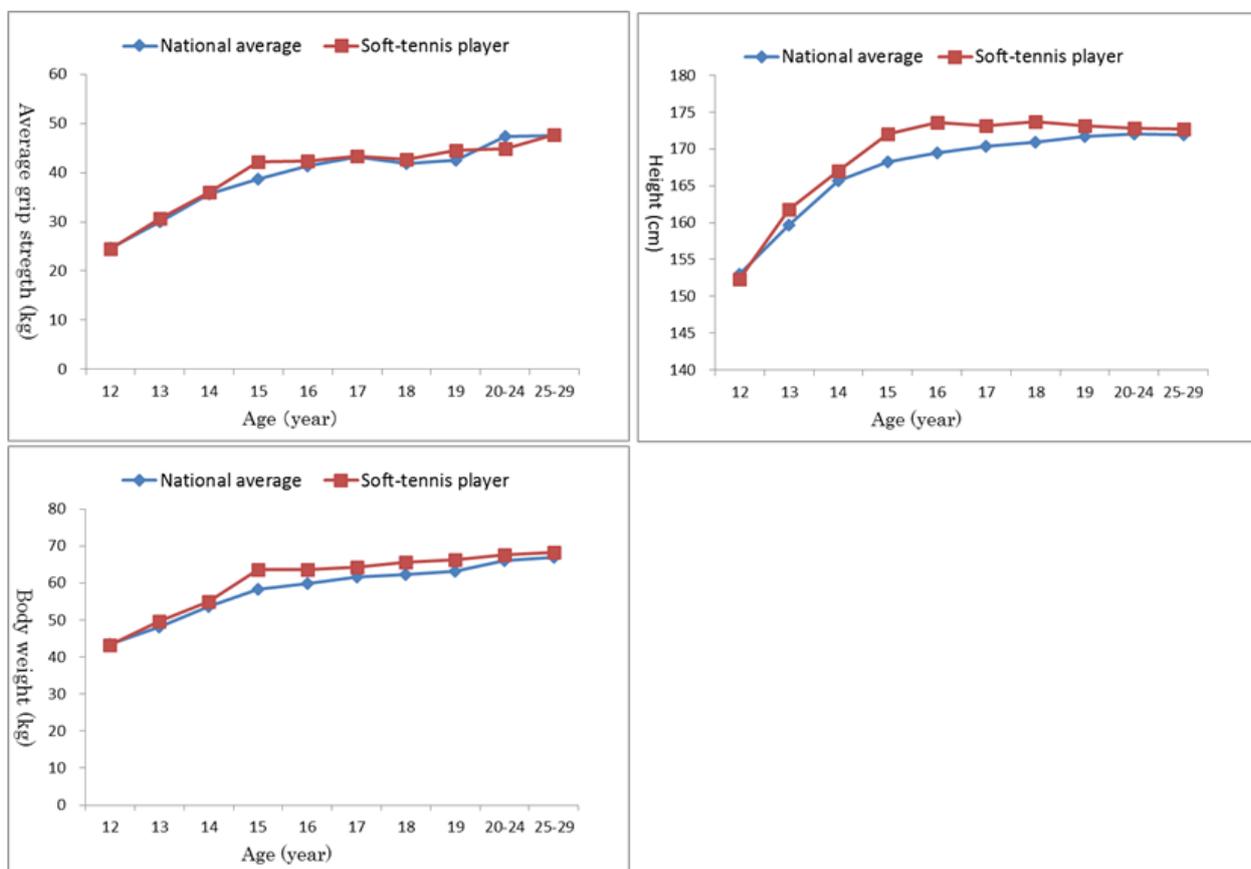
The participants were 468 male elite soft-tennis players (age range: 12–29 years) with participation experience in a national athletic meet. As strong tennis skills are required to win a provincial preliminary tournament or block meet and thus allow participation in a national athletic meet, we considered these participants to be elite soft-tennis players. The players were classified into groups according to age in years. Table 1 presents basic statistical data concerning the sample size for each age group as well as height, body weight, and grip strengths of the dominant and non-dominant hands. In this table, players older than 23 years were integrated into a single group as working people.

Figure 1 presents the mean height, body weight, and grip strength values of the participants in this study, as well as national mean values derived using a new physical fitness test [11] according to age level. Players aged 20–24 and 25–29 years were clustered into separate groups. The national mean grip strength, which comprises the mean of the right and left hand grip strengths, was used as a representative value in a new physical fitness test. Accordingly, the mean values from the present study were plotted to correspond with the age groups used in this new physical fitness test to facilitate comparison. The heights and body weights of soft-tennis players were almost the same as the national means for age groups over 20 years, although these values were slightly larger for soft-tennis players aged 15–19 years. The average grip strength of soft-tennis players was almost the same as that of the overall national mean value.

**Table 1.** Basic statistical data concerning height, body weight, and dominant and non-dominant grip strengths according to age among male elite soft-tennis players

Age (year) (n)		12 (n=7)	13 (n=10)	14 (n=28)	15 (n=38)	16 (n=31)	17 (n=71)	18 (n=67)	19 (n=58)	20 (n=51)	21 (n=25)	22 (n=25)	23~ (n=57)
Height (cm)	M	152.3	161.8	167.0	172.0	173.5	173.2	173.7	173.1	173.3	172.8	171.4	173.7
	SD	8.6	6.0	6.1	5.3	4.7	5.3	4.9	4.4	4.7	4.6	5.2	4.5
Weight (kg)	M	43.2	49.7	55.1	63.6	63.7	64.3	65.5	66.2	67.2	67.9	65.3	70.5
	SD	6.6	5.2	7.7	7.5	5.6	5.5	5.5	4.8	5.5	6.1	7.0	6.5
The dominant hand grip strength	M	26.7	33.6	40.0	46.8	47.0	48.7	47.1	48.9	49.3	49.4	48.9	53.1
	SD	7.0	8.8	6.7	6.7	7.4	5.4	5.0	5.4	4.8	5.3	4.5	4.6
The non-dominant hand grip strength	M	22.2	27.8	31.9	37.7	37.5	38.2	38.1	40.0	39.3	39.7	38.7	42.7
	SD	6.2	7.0	6.1	6.1	6.8	5.5	5.3	5.4	5.0	5.4	5.3	4.4

n= sample size, M=mean, SD=standard deviation.



**Figure 1.** Mean grip strength, height, and body weight among soft-tennis players and corresponding national averages

## 2.2. The Dominant and Non-dominant Hand

Demura et al. [12] constructed a handedness inquiry to determine the dominant hand. In this study, we defined the hand used to hold the racket as the dominant hand because soft-tennis players held their rackets on only one side.

## 2.3. Grip Strength Measurement

Grip strength was measured in kg using a grip strength dynamometer (T.K.K. 5401 Grip-D, Takei, Tokyo, Japan) in reference to the manual of a physical fitness test supplied by the Ministry of Education, Culture, Sports, Science, and Technology in Japan. Grip strength was measured twice each in the dominant and non-dominant hands, and the larger value for each hand was selected. The absolute value of the difference in grip strength between hands was used as a representative value. In addition, mean grip strengths of both hands of soft-tennis players were calculated for comparison with national average values (Figure 1).

## 2.4. Statistical Analysis

SPSS 18 software (SPSS Inc., Chicago, IL, USA) was used to conduct statistical analyses. A two-way repeated-measures analysis of variance (ANOVA; age × dominant/non-dominant hands) was used to reveal differences among mean values. When significant effects were observed, we performed a multiple comparison test using the Bonferroni method. A one-way factorial ANOVA was used to reveal differences among the mean grip strength values according to age. Again, when a significant difference was found, a multiple comparison test was performed using a Bonferroni method. The level of significance was set a priori at 0.05. In addition, an effect size (ES) was calculated to examine the sizes of mean differences. ES was interpreted as follows: <0.2, small; >0.5, intermediate; and >0.8, large (Demura et al., 2009).

## 3. Results

Figure 2 shows the mean grip strengths (and standard deviations) in the dominant and non-dominant hands and differences in grip strength according to age, as well as the results of two-way repeated-measures ANOVA, one-way factorial ANOVA, and multiple comparison tests. Two-way repeated-measures ANOVA failed to identify significant interactions ( $df = 11, F = 0.45, p = 0.92, \eta^2 = 0.06$ ); however, both the main factors of age ( $df = 11, F = 3.96, p < 0.05, \eta^2 = 0.37$ ) and dominant and non-dominant hands ( $df = 1, F = 373.02, p < 0.05, \eta^2 = 0.83$ ) were found to be significant. In the multiple comparison test, a significant difference was identified between the dominant and non-dominant hands in age groups over 14 years [ES (d) = 1.26–2.32]. The dominant hand grip strength was lower in the 12-year-old group relative to age groups over 14 years [ES (d) = 2.94–4.46], in the 13-year-old group relative to age groups over 15 years [ES (d) = 1.68–2.77], and in the 14-year-old group relative to the 17, 19, 20, and 23-year-old age groups [ES (d) = 1.43–2.29]. The non-dominant hand grip strength was smaller in the 12-year-old group than in the 15-year-old group and all groups over 17 years [ES (d) = 2.51–3.80], and it was smaller in the 13- and 14-year-old groups than in the groups over 23 years [ES (d) = 1.30 (13 vs. over 23), 0.48(14 vs. over 23)].

One-way factorial ANOVA indicated significance ( $df = 11, F = 2.60, p < 0.05, \eta^2 = 0.06$ ). In the multiple comparison test, the grip strength difference was smaller in the 12-year-old group than in the age groups over 14 years [ES (d) = 1.09–1.70], in the 13-year-old group than in the age groups over 15 years [ES (d) = 0.88–1.19], and in the 14-, 18-, and 19-year-old groups than in the 17-year-old group [ES (d) = 0.34–0.58]. ES is generally considered large at values >0.80 (Demura et al., 2009). ES in the 17-year-old group vs. 14-, 18-, and 19-year-old groups was smaller than that in the 12-year-old group vs. age groups over 14 years and in the 13-year-old group vs. age groups over 15 years.

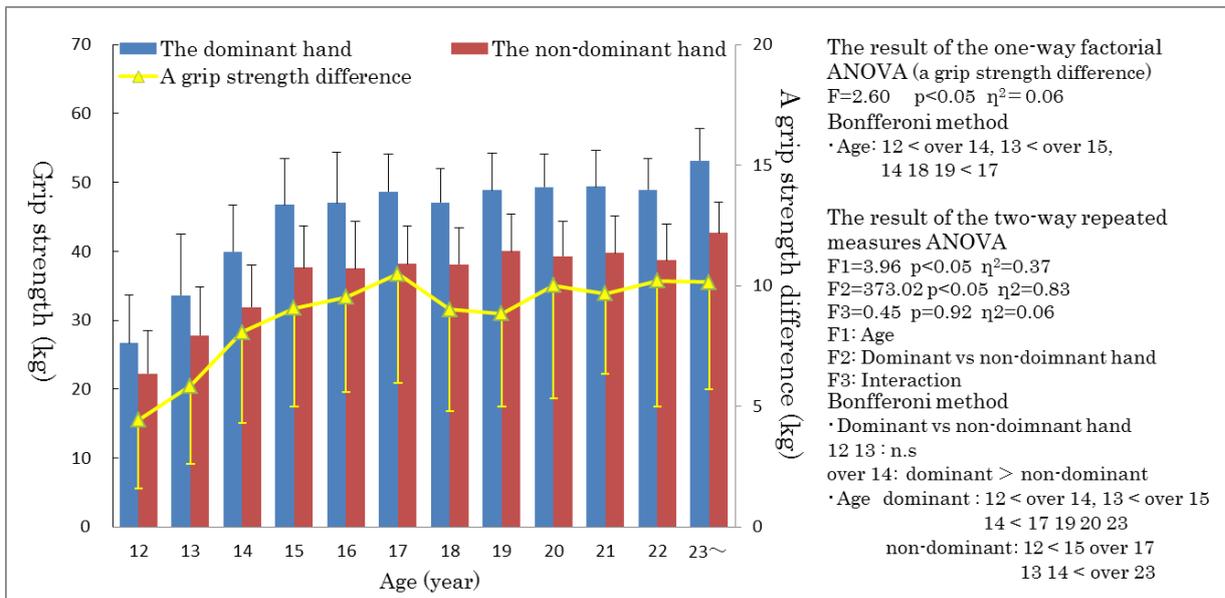


Figure 2. Means and standard deviations in grip strengths of the dominant and non-dominant hands and grip strength differences in each age group and the statistical results

## 4. Discussion

In this study, the average grip strength of participating soft-tennis players was found to be almost the same as the overall national mean grip strength, although this value was slightly greater among 15-year-old soft-tennis players than among the overall age-matched population. This supports the earlier findings of grip strength laterality in the general population, as well as among athletes [13], such as those reported by Kubota et al. [8,9], and Nagasawa et al. [10], regarding grip strength in a general student population and controlled force grip strength exertion in elderly population.

Maie and Mashui [14] reported grip strengths of 45.5 kg and 42.2 kg in the dominant and non-dominant hands, respectively, of adult men (mean age: 21.7 years) and of 19.0 kg and 16.9 kg, respectively, in students from grades 5 and 6 of an elementary school (mean age: 10.6 years), with a nearly identical grip strength difference ES in both groups (ES = 0.53). According to Hirano et al. [15] in a study of healthy adults (mean age: 31.2 years), the respective mean grip strengths of the dominant and non-dominant hands were 40.7 kg and 37.9 kg in exercise continuators and 38.6 kg and 36.0 kg in non-exercise continuators; notably, the difference in grip strength was the same in both groups (ES=0.26, 0.27), although the former group had greater grip strength values. The differences in grip strength between the dominant and non-dominant hands in this study were 4.4 kg (ES = 0.67) at 12 years, 10.2 kg (ES = 2.09) at 22 years old, and 11.2 kg (ES = 2.68) at 29 years. The following can be inferred from the above information: grip strength laterality exists independently of athletic experience. In addition, grip strength increases with age in both hands, whereas the degree of laterality remains nearly constant regardless of age. In addition, the difference between right and left grip strength is greater in soft-tennis players than in the general population.

Yoshida et al. [16] reported that the respective dominant and non-dominant hand grip strengths of athletes (mean age: 22.6 years, range: 20–29 years) belonging to the Japan national team that participated in the 1985 Summer Universiade were 51.1 kg and 49.4 kg in track and field athletes, 50.4 kg and 48.3 kg in basketball players, 46.4 kg and 44.4 kg in soccer players, and 50.4 kg and 48.6 kg in volleyball players. The corresponding values among soft-tennis players aged 20–29 years in the present study (mean age: 22.3 years) were 50.4 kg and 40.5 kg, respectively. In a study of university athletes, Wakabayashi et al. [17] reported respective dominant and non-dominant hand grip strengths of 42.8 kg and 39.8 kg in track and field athletes (n = 20), 48.0 kg and 46.2 kg in soccer players (n = 19), 51.6 kg and 49.0 kg in judo competitors (n = 19), 48.4 kg and 48.5 kg in baseball players (n = 19), 51.3 kg and 48.5 kg in swimmers, and 48.2 kg and 41.2 kg in lawn-tennis players. In comparison, corresponding values for soft-tennis players aged 19–22 years in the present study were 49.1 kg and 39.6 kg, respectively.

Despite similarities in dominant hand grip strength between soft-tennis players and athletes whose sports involve grasping behaviors (e.g., judo, baseball, and lawn-tennis), the non-dominant hand grip strength of

soft-tennis players was inferior to that of athletes whose sports did not involve grasping behaviors (e.g., soccer and swimming) and similar to those observed in track and field athletes and lawn-tennis players. In other words, soft tennis-players have a very similar dominant hand grip strength but inferior non-dominant hand grip strength relative to other athletes. Yoshida et al. [16] reported grip strength differences between dominant and non-dominant hands of 0.7–2.1 kg in track and field athletes, basketball players, soccer players, and volleyball players. In contrast, a 9.9-kg difference was observed among soft-tennis players in the present study; in other words, the difference was greater in soft-tennis players relative to athletes in the earlier study. Similarly, Wakabayashi et al. [17] reported a grip strength difference of 7.0 kg in lawn-tennis players compared with only 0.6–2.2 kg in other athletes (track and field, soccer, judo, baseball, and swimming).

Asami [13] reported differences of 7.71 kg in handball players, 6.72 kg in track and field throwers, 5.76 in swimmers, 5.26 kg in volleyball players, and 0.3 kg in rugby ball players. In handball, track and field throwing, and volleyball, athletes do not use a racket and can use either hand to meet their objectives (e.g., manipulating a ball or object). In the present study, soft-tennis players aged 19–22 years exhibited differences in the grip strength of 8.9–10.2 kg, which were larger than the values reported by Asami [13]. Because the competitive nature of racket sports limits performance to the dominant hand, the dominant hand is frequently required to exert a high amount of grip strength during practice and matches, whereas the non-dominant hand is rarely taxed. Hence, a larger difference in grip strength would be expected in soft-tennis players. Track and field athletes, soccer players, and swimmers rarely exhibit unilateral upper limb performance during competition, and thus, these athletes maintain a right/left difference in grip strength similar to that in the general population. Although basketball, handball, and volleyball players mainly use the dominant hand when pitching and hitting, they may also use the non-dominant hand. Accordingly, they might not develop a large grip strength laterality.

Aouda et al. [18] reported that the dominant and non-dominant hand grip strengths of junior high school basketball players (mean age: 13.9 years) were 34.5 kg and 32.4 kg, respectively (ES = 0.33). In the present study, the corresponding values of 13- and 14-year soft-tennis players were 33.6 kg and 27.8 kg (ES = 0.73) and 40.0 kg and 31.9 kg, respectively (ES = 1.26). In short, ES was larger in soft-tennis players. In a study of junior male elite table-tennis players (mean age: 12 years), Luis et al. [7] reported respective dominant and non-dominant hand grip strengths of 27.4 kg and 22.5 kg for right-handed players (n = 25) and 26.4 kg and 22.0 kg for left-handed players (n = 13). The respective grip strength differences and ESs were 4.9 kg and 1.07 among right-handed players and 4.4 kg and 0.92 among left-handed players, indicating a larger difference in the former. In the present study, the corresponding values for 12-year-old soft-tennis players were 4.4 kg (26.7–22.2 kg) and ES = 0.67, which were nearly identical to those of elite table-tennis players.

In a study of wrist and forearm isokinetic strength in junior female elite lawn-tennis players (mean age: 13.7 years), Ellenbecker et al. [19] reported increased peak

torque and single repetition work per body weight values in the dominant hand relative to the non-dominant hand and a marked increase in upper limb strength laterality from the early teens. The above information suggests that upper limb laterality in young players (i.e., 12–14 years) is marked in tennis or table-tennis players who mainly grasp a racket with the dominant hand compared with basketball players who often use both hands. The present study results further confirmed that grip strength in both the dominant and non-dominant hands markedly increased with age in soft tennis-players between 12 and 15 years of age. During this period, grip strength as well as height and weight rapidly develop as a result of an adolescent growth spurt and emergence of secondary sex characteristics, leading to remarkable age-related differences [20]. This difference in grip strength between the dominant and non-dominant hands continues to increase up to 17 years of age, with a remarkable average increase of 4.5 kg from 12 to 15 years of age ( $ES = 1.32$ ).

The difference in grip strength between dominant and non-dominant hands was similar in the general populations of adults and elementary school-aged children, according to a report by Maie and Mashui [14]. In contrast, the 12-year-old soft-tennis players in this study had participated in specialized soft-tennis training for several years. Accordingly, players older than 14 years exhibited a marked and very large difference in grip strength between the dominant and non-dominant hands ( $ES = 1.26$ – $2.32$ ). Despite this increase in grip strength laterality in athletes older than 14 years, the difference remains stable beyond 17 years of age because the grip strengths do not tend to increase further with age. Soft-tennis players older than 17 years have long athletic careers but reach a plateau of physical fitness. Hence, the grip strength difference between the dominant and non-dominant hands is thought to remain approximately constant. Hinder et al. [21] reported that in young people (mean age: 21.1 years), continual training to increase muscle strength in the dominant arm also improved the non-dominant arm. Hence, it is possible that muscle strength development in the dominant side also affects the non-dominant side, thus mitigating differences in strength beyond a certain level.

According to Zhao et al. [22] in a study of female university badminton players (mean age: 18.9 years), grip strength was greater in the dominant hand than in the non-dominant hand; when compared with general university students, the athletes had greater strength in the dominant hand but similar strength in the non-dominant hand. Although male soft-tennis players were the target population in the present study, a similar grip strength difference was also confirmed in female players. The age at which this difference becomes remarkable might differ between men and women as a result of differences in the expression of secondary sexual characteristics. As a result, future studies will need to evaluate female soft-tennis players and compare the findings with those of male athletes.

Petersen et al. [23] reported that in a general adult population (age range: 17–50 years) that included many university students, right-handed persons had a 9.2% greater grip strength in the right hand than in the left hand, whereas in left-handed persons, the left hand grip strength was only 1.9% greater in the left hand. Luís et al. [7]

reported that both right- and left-handed junior elite table-tennis players had greater grip strength in the dominant hand than in the non-dominant hand, and the difference in grip strength was the same between right- and left-handed players. In short, although the difference in grip strength was greater in right-handed people than in left-handed people in a general population, athletes who continuously train in sports requiring unilateral racket use (e.g., table-tennis) might have large differences in grip strength, regardless whether the left or right hand is dominant. In the present study, we examined differences in grip strength between dominant and non-dominant hands only according to age. In future, it will be required to examine such differences between right- and left-handed persons, as described by Luís et al. [7].

## 5. Conclusion

In conclusion, in male elite soft-tennis players, grip strength in both the dominant and non-dominant hands develops with age up to approximately 17 years and changes only slightly after that point. Notably, marked development was observed from 12 to 15 years of age. Differences in grip increased with age and became remarkable in players older than 14 years, but remained almost constant in players older than 17 years. Differences in grip strength in male elite soft-tennis players are expected to be similar to those in elite athletes of other racket sports (e.g., lawn- and table-tennis) but greater than those in elite athletes participating in other sports such as judo, track and field, swimming, baseball, soccer, rugby, volleyball, and basketball.

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