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Factors associated with hand grip strength in martial arts

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Abstract

Backgound: Handgrip strength is an important metric used in sports and helps measure athletes' conditions. It is affected by many factors, including athletes' age, body weight, skills, or years of training. Unfortunately, at least in martial arts, associations among those factors are not apparent. **Methods**: In the study, 178 athletes training in martial arts (Jujitsu and Karate) were evaluated for their age, years of training, body weight, and skills (belt grade). HGS was measured via the dynamometric measurement of hand force. Moderation analysis was employed to evaluate the relationships between athletes' body weight and handgrip strength and between athletes' skills and handgrip strength. **Results:** It was shown that athletes' body weight and HGS are moderated preferentially by athletes' age and then by years of training. It was demonstrated that HGS could be improved by athletes younger than 52 years old. Years of training also moderate the relationship, but the moderation is limited to 39 years of training. The relationship between athletes' skills and HGS is illustrated by moderated moderation, where triple interaction among skills, age and years of training can explain an additional 12.9% of the HGS variance. **Conclusions:** The presented study may be used to evaluate relationships between numerous variables associated with HGS and could be vital for constructing statistical models for trainers' purposes.

Keywords: martial arts, body weight, age, years of training, skills, handgrip strength, moderation analysis

Introduction

Handgrip strength (HGS) is a crucial component of biomechanical modelling extensively used in creating ergonomic instruments, designing machinery and consumer goods, and in athletic training (1-8). It is one of the critical metrics for measuring muscle power since HGS is essential for the human body when performing precise hand actions (9). Additionally, it is a low-cost method of estimating a person's total strength, which may reflect physical activity and general health (10). The relationships between powerlifting performance and HGS was described (11). Body size, age, training, and gender are physiological variables affecting HGS (12). Numerous studies (9, 13, 14) have examined the links between HGS and many other factors, but what affects HGS the most is still being determined.

Males tend to have stronger arms and participate in more physically demanding activities than females. Moreover, males have a larger size and more muscle mass, and muscle strength depends on these traits. Strong associations between HGS and body measurements, such as body weight, height, and hand length, have been noted (15-21), as has a positive correlation between HGS and the percentage of lean body mass in cricket players (22). Furthermore, HGS and the percentage of lean body mass have been indicators for determining strength (23). It was demonstrated that judo and karate athletes differ in HGS and that there is a correlation between HGS and BMI (24). Higher HGS is correlated with a higher number of attacks and shows higher effectiveness in judo competition (25). However, the findings concerning body mass index (BMI) are debatable. While some authors reported a positive relationship between static HGS and BMI, considering it a predictor for HGS, others found no significant association and concluded that BMI has no bearing on HGS (14, 26).

The dominant hand's HGS is significantly influenced by the forearm size, wrist joint circumference, palm circumference, hand length, and middle finger length (14, 27-31). Physical workers typically have stronger grips than non-manual labourers, so job duties can also impact HGS (26). Furthermore, HGS is related to physical activity (32). It is also related to sport, as demonstrated in Brazilian jujitsu (BJJ); athletes with higher experience, training, and level (expert group) have more adaptations and improvements than the novice group. Their higher records can be seen in isometric handgrips and the higher explosive strength in their legs (33).

In addition, hand grip varies depending on laterality, with the dominant hand maintaining a firmer grip than the non-dominant hand (26). It is likely due to the larger and stronger muscles on

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the dominant side of the body due to the dominant hand being exploited more vigorously than the non-dominant one. However, this is only true for those with a dominant right hand; for those with a dominant left hand, the difference is less pronounced and occasionally even insignificant (14, 26, 34). Regarding this, it is crucial to keep in mind that people exhibit functional variations on the right and left sides of each bilaterally symmetrical body part (35-39). Latitudinally dominant muscle function has already been widely documented. Notably, laterality is a multidimensional feature, and 90% of adults prefer to use their right hand for everyday manual tasks, whereas 10% of the population uses their left hand (40-43). Another significant finding is that lateralization is a highly active process throughout life and is impacted by genetic and environmental variables (43-49).

Age significantly influences HGS, which has been shown to have a curvilinear relationship. As a result, HGS increases with age, peaks between 30 and 40, and then declines afterwards. Females exhibit a stronger non-linear relationship than males, which varies between the sexes. Compared to females, males can maintain their HGS for at least the next ten years (26, 27, 50, 51). Males typically have stronger grips than females, and this difference between the sexes is noticeable at all ages (26, 50, 52-54).

Finally, to study relationships among factors affecting body weight, HGS, age, years of training, and skills moderation and mediation analysis could be employed (55). The approach is primarily used in psychology (56), medicine (57, 58), and economic and business sciences (59). It allows the identification of moderators or mediators in biological studies (60) and was also employed in sport management (61, 62). It may have a wide range of applications, allowing a better understanding of relationships among many factors in martial arts.

Furthermore, sports research predominantly relies on existing theories developed in allied disciplines. This is likely because there is a perceived lack of need to adapt, extend, or generate new theories. Additionally, there are relatively few theories that originate in sport (61). However, developing particular sports theories, such as those presented by Green (63) or Funk (64) and utilized in sport management, is required. Moreover, new theories are required to understand the relationships between numerous factors significant in sport.

It is also vital to implement sophisticated approaches to modeling such associations. Some of them, including moderation analysis, were applied, i.e., in sports management (62), motivation (65, 66), or revealed the antisocial role of narcissism in sport (67). Mediation analysis was employed to study effects of lean mass and fat mass on the relationship between body mass index (BMI) and handgrip strength (68, 69) but no such studies are available in martial arts. Obviously, further research is required on similar studies involving HGS.

We hypothesize that age and years of training may moderate the relationship between body weight and HGS. Furthermore, skills (grades) may impact HGS, and the relationship is moderated by the athlete's age possibly including moderated moderation via years of training. Additionally, distinct martial arts might impact the relationship. To our knowledge, studies addressing the issue and utilizing moderation analyses still need to be conducted. To verify the working hypothesis, the abovementioned relationships will be tested on men training in Jujitsu and Karate, utilizing moderation analysis.

Materials and Methods

The authors conducted a survey personally to gather data for their study. The survey was directed among the participants who attended several independent sports events like instructor mastery courses and advanced training sessions in Poland and Germany from 2018 to 2022. The athletes were asked whether they had undergone any surgeries involving their upper limbs in the past year. Their muscle pain and stress injuries were also confirmed. There were no specific criteria other than age (18 and above) and higher belt ranks (higher skills) to choose the survey participants. Those who did not meet the criteria were excluded from the analysis. The participants who accepted the invitation were weighed, and their handgrip strength was measured. They also declared their belt ranks, age, years of training, gender, and style, which included two groups of modern Jujitsu, karate Shotokan and karate Kyokushin. The study collected data from 178 participants and tested their age, body weight, years of training, skills (Kyu or Dan grade), and HGS.

Handgrip strength is a widely used fitness test in judo and karate to evaluate upper-limb strength (24). It has been found to correlate with body mass (70) and its composition (71). However, HGS is ineffective in distinguishing athletes who practice Brazilian Jiu-Jitsu (BJJ) (72). Studies have shown that HGS can differentiate between the skill levels of white and black belt judokas, making it a valuable tool in martial arts (73). Furthermore, it has been observed that experienced athletes who practice arm wrestling tend to have higher handgrip strength (74). Therefore, HGS could be used to differentiate between athletes practicing different martial arts.

The analysis took into account the Kyu and Dan ranks, as they were found to be associated with body mass and HGS (75). Additionally, research has demonstrated that HGS can be used to distinguish between the skill levels of white and black belt judokas, making it a valuable metric in martial arts (73).

Groups of participants:

Group 1. – Jujitsu 1, athletes from Poland (24 persons)
Group 2. – Jujitsu 2, athletes from Germany (96 persons)
Group 3. – Karate Kyokushin (36 persons)
Group 4. – Karate Shotokan (22 persons)

The HGS test, involving the dynamometric measurement of hand force, was carried out as follows: Dynamometer model: KERN MAP 130K1 (manufacturer KERN) palm hand dynamometer was used. The subject squeezes the hand dynamometer with a stronger hand. The wrist should lie along the extension line of the forearm. During this testing, the test hand must not touch any part of the body (76, 77). The strength of the hand is measured in kilograms. The better measurement of the two tests was selected for further analysis. The dynamometer should be adjusted to the size of the hand of the subjects so that the more distal finger joints fit in its handle. Hand swings during measurements are not allowed because they can alter the results. Subjects need to focus mentally on the task since the goal is to measure the maximum HGS force of the subjects (76).

Pearson and Spearman correlation coefficients, analysis of variance, and principal component analysis (PCA) were conducted in XlStat software (78).

Moderation analysis was conducted in SPSS v. 27, utilizing Process Macro v 4, evaluated by Hayes (79, 80). The term "moderation analysis" refers to a relationship between two variables (X and Y) where one variable (W) influences the other, changing the strength of the relationship. Sometimes, a second factor (Z) may impact the moderator's (W) strength. In such a case, a moderated moderation model is assumed. The analysis was conducted in SPSS software V. 27 (https://www.ibm.com/support/pages/node/874712) using the A. F. Hayes Process macro (55). Simple moderation model 1 (Figure 1a) and moderated moderation model 3 (Figure 1b) were tested.

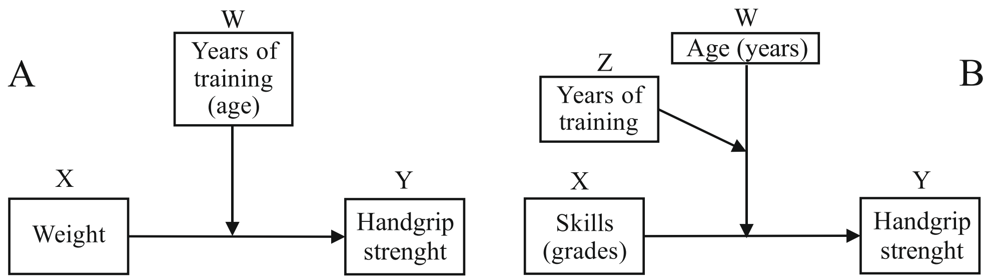

Figure 1. Schematic illustration of the conditional moderation model. A) X is the body weight (kg); Y is the outcome variable called HGS, W states for Years of training (age); B) Schematic illustration of conditional moderation model. X states for Skills (grades), Y is the outcome variable reflecting HGS, W states for athletes' ages conditional on Years of training (Z).

Results

The study involves participants of different ages and years of training. Furthermore, the athletes varied in body weight; however, there were no fat parsons, and the body weight should be treated as a lean body mass. Several martial arts, including two karate styles (Kyokushin and Shotokan) and a jujitsu group from Poland and Germany, are represented by athletes with varying grades. The participants also differ in terms of HGS. The statistics describing the variables used in the analysis are given in Table 1.

Table 1. Descriptive statistics

Variables	Min	Max	Mean	SD	Variance
Age	12.00	61.00	36.1404	13.04089	170.065
Years of treining	4.00	56.00	19.0562	10.00662	100.132
Body weight	43.00	125.00	79.2528	14.14406	200.054
Skills	0	7	-	-	-
Martial arts	1	4	-	-	-
HGS	20.00	106.00	80.2978	16.85954	284.244

To determine how the athletes' age (W) moderates relationships between their body weight (a predictor and independent variable (X)) and handgrip strength (HGS) (the outcome variable—Y), a moderation analysis was carried out. We used a simple moderation model to calculate the athlete's age's moderating effect. All of the variables of simple moderation (Table 2) appeared to be significant, regardless of training years or age. The overall two-way interaction model for years of training and age accounted for 46.1 and 50.3% of the total variance explaining HGS by body weight (F (3.174) = 33.05, p < 0.001) and body weight (F (3.174) = 55.635, p < 0.0001), respectively. Additionally, the two-way interaction of body weight by years of training and body weight by athletes' age explained 2.44% (F(1,174) = 8.322, p 0.001) and 6.73% (F(7.27) = 22.174%, p 0.001) of the variance, respectively. Body weight and years of training, as well as body weight and athletes' ages, both had significant and adverse two-way interactions, according to the simple moderation model (b = -0.0207, SE = 0.0072, p 0.001) and (b = -0.0263, SE = 0.0056, p 0.001). The Johnson-Neyman significant region based on the conditional effect of focal predictor (body weight) at the moderator's (age) values is significant until 51.79. The effect is positive (Figure 2). The Johnson-Neyman significant region for years of training is positive and significant until 39.03 years of training based on the conditional effect of the focal predictor (body weight) at values of the moderator (years of training) (Figure 3).

Table 2. The simple moderation model showing an interaction among athletes' body weight, their age (years of training) on HGS. β reflect standardized effects; LLCI and ULCI indicate confidence intervals (LLCI -lower, UPLCI upper) whereas SE is a standard error of β.

Predictors	Statistics			
	β	SE	95% LLCI	95% ULCI
Athletes body weight Years of training (age)	1.1103*** (1.609***)	0.2663 (0.1964)	0.782 (1.2204)	1.4385 (1.9976)
Athletes Years of training (age)	1.6942*** (2.1134***)	0.592 (0.454)	0.5258 (1.2174)	2.8626 (3.0095)
Athletes body weight × Athletes Years of training (age)	-0.0207*** (-0.0263***)	0.0072 (0.0056)	-0.0398 (-0.0373)	-0.0065 (-0.0153
Model Summary for Athletes years of training (age)	R2 = 0.4613, F (3,174) = 33.0522, MSE = 155.77, p < 0.001 (R2 = 0.5053, F (3,174) = 55.6349, MSE = 143.0352, p < 0.001)			
Test of highest order unconditional interaction (X × W: Athletes body weight × Athletes Years of training (age)	F(1,174) = 8.322, R2chng = 0.0244, p < 0.001 (F(1,174) = 22.174, R2chng = 0.0673, p < 0.001)			

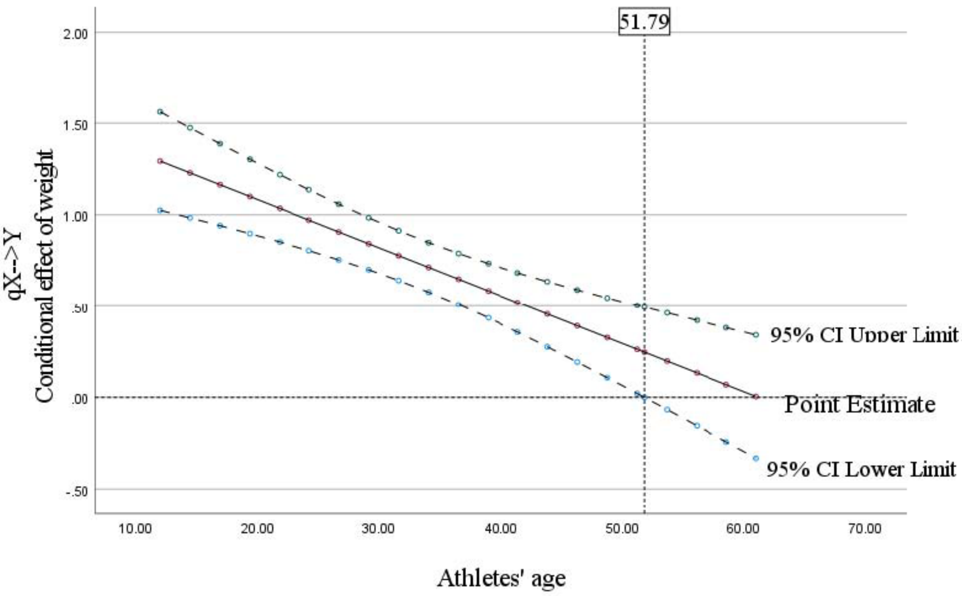

Figure 2. The conditional effect of the body weight ($q_{X\rightarrow Y}$) on HGS for withholding aid as a function of athletes' age.

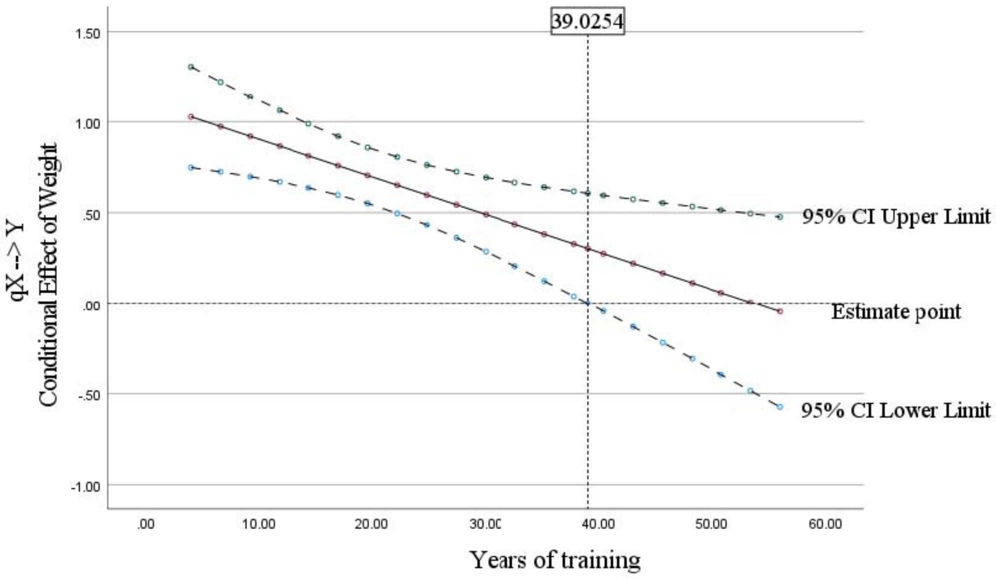

Figure 3. The conditional effect of the body weight ($q_{X \to Y}$) on HGS for withholding aid as a function of years of training.

Furthermore, we have tested how years of training (Z, Figure 1B) influence the extent to which athletes' ages (W) moderate relationships between skills (an independent variable (X)) and HGS (the outcome variable—Y). By employing a three-way interaction model, we estimated the moderating influence of years of training (Z), which operates as a secondary moderator. All the predictors of moderated moderation appeared significant (Table 3). The overall three-way interaction model for athletes' ages accounted for 40.85% of the total variance explaining the HGS by the skills ($F(7, 170) = 10.7246$, $p < 0.0001$). Furthermore, the three-way interaction of skills by years of training and athletes' ages accounted for 7.73% ($F(1,170) = 12.8861$, $p = 0.0004$) of the variance. The moderated moderation model showed significant and positive three-way interaction between skills, age, and years of training ($\beta = 0.0351$, $SE = 0.0098$, $p < 0.001$) (Table 3). Johnson–Neuman's statistics indicated that the conditional effect of skills (X) x athletes' age (W) interaction at values of the years of training moderator (Z) was negative and significant until 12.25 years of training. Then, it became significant and positive after 45 years of training (Figure 4).

Table 3. The moderated moderation model showing three-way interaction among Skills, Years of training and Age on HGS. β reflect standardized effects; LLCI and ULCI indicate confidence intervals (LLCI -lower, UPLCI upper) whereas SE is a standard error of β

Predictors	Statistics			
	β	SE	95% LLCI	95% ULCI
Skills	40.93***	13.2802	20.7146	73.1455
Age	1.6383****	0.2335	1.1774	2.0992
Skills x Age	-0.8822**	0.2839	-1.4427	-0.3216
Years of training	4.0148	0.8754	2.2867	5.7428
Skills x Years of training	-2.01**	0.6128	-3.2197	-0.8003
Age x Years of training	-0.0721****	0.0144	-0.1004	-0.0438
Skills x Age x Years of training	0.0351***	0.0098	0.0158	0.0544
Model Summary for Age	R2 = 0.4085, F (7,170) = 10.7246, MSE = 175.04, p < 0.0001			
Test of highest order unconditional interaction (X × W × Z: Skills × Age × Years of training)	F(1,170) = 12.8861, R2chng = 0.0773, p = 0.0004			

The effect of athletes' body weight on HGS depends on athletes' years of training (Figure 5). Years of training increase HGS with body weight. However, at lower body weight values, HGS is higher for athletes who are training longer. On the other hand, more extended training has a less significant effect on HGS for body weightier athletes.

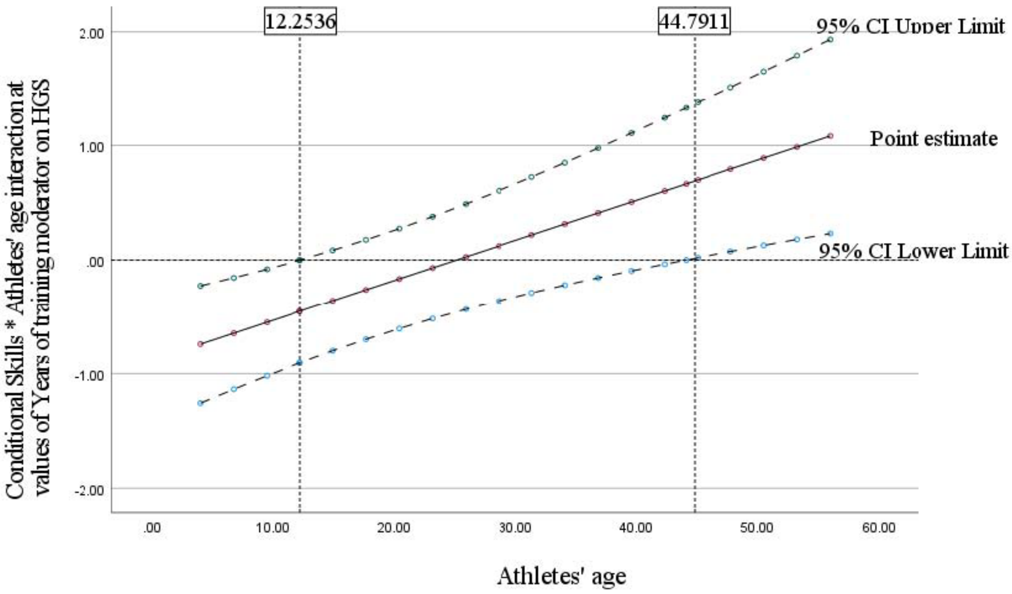

Figure 4. The conditional effect of Skills x athletes' Age interaction at values of Years of training on HGS

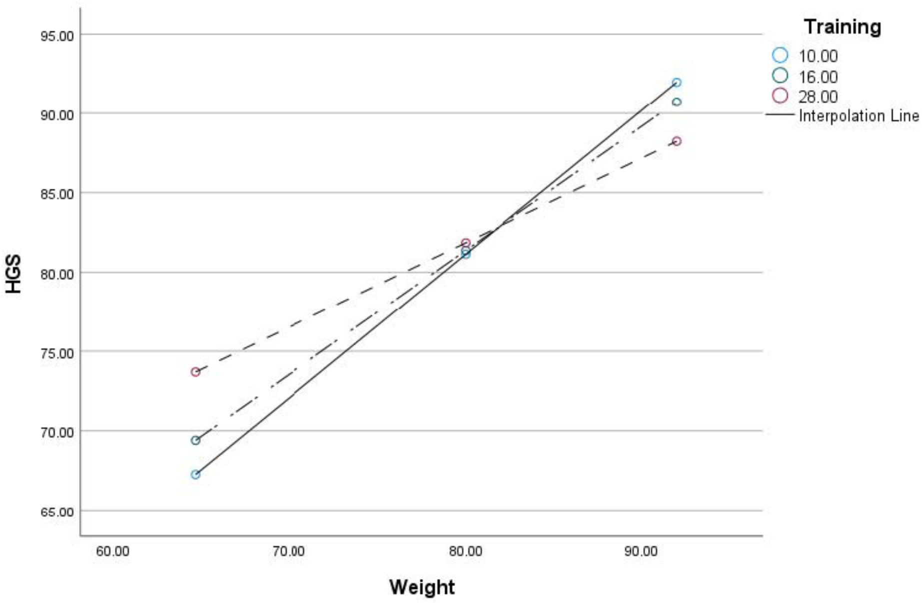

Figure 5. The conditional effect of athletes' body weight on HGS as a function of years of training based on a simple moderation model. The category axis (axis of abscissa) is indicated as body weight. It illustrates the values of athletes' body weight in kg. The axis of ordinates reflects HGS. Blue, red, and green circles indicate the different years of training (indicated as Training).

Similarly, as in the case of years of training, relationships are observed for athletes' ages (Figure 6). However, the differences concerning the effect of body weight on HGS mediated by the athlete's age are more pronounced.

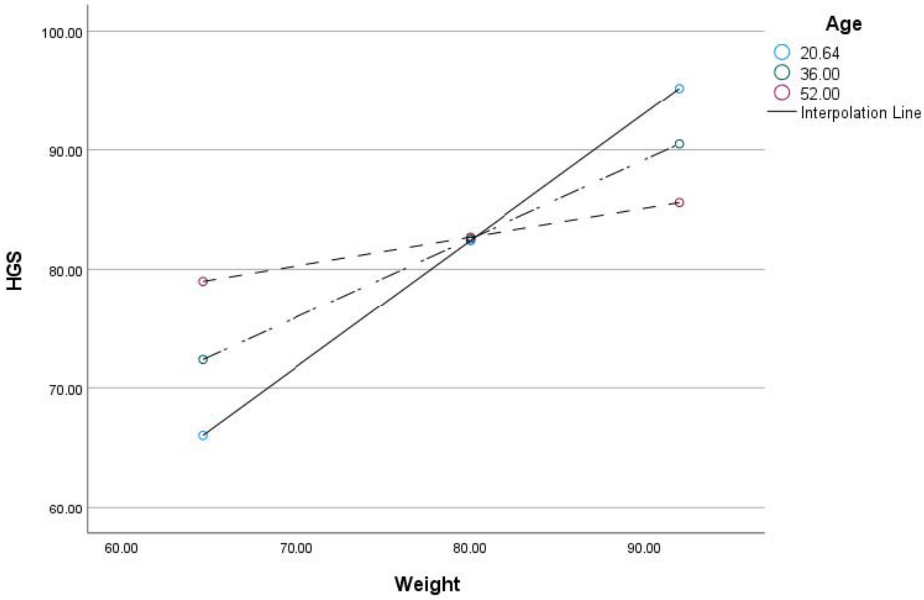

Figure 6. The conditional effect of athletes' body weight on HGS as a function of age based on a simple moderation model. The category axis (axis of abscissa) is indicated as body weight. It illustrates the values of athletes' body weight in kg. The axis of ordinates reflects HGS. Blue, red, and green circles indicate the different athletes ages.

The effect of skills on HGS depends on athletes' ages and years of training. HGS increases with skills for young athletes (ca. 21 years old), and the rise is more pronounced for those training less than 16 years. When the older athletes (52 years old) are considered, HGS either does not change or decreases with skills and years of training (Figure 7).

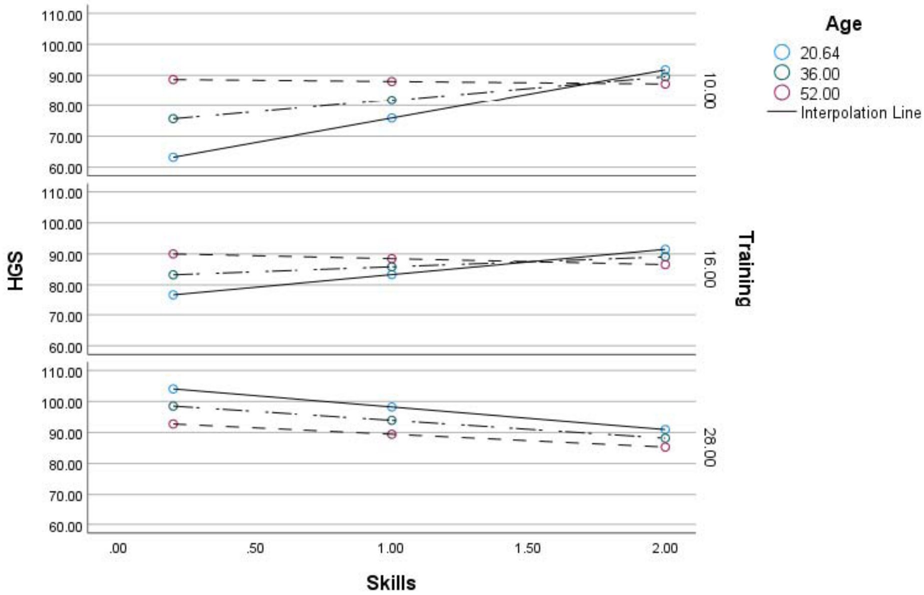

Figure 7. The conditional effect of skills on HGS as a function of age and years of training from the moderated moderation model. The category axis (axis of abscissa) is indicated as "skills." It illustrates the value of skills (grades). The axis of ordinates reflects the HGS. Blue, red, and green circles indicate the different ages, whereas successive figures reflect years of training (indicated as Training).

Discussion

HGS is a fundamental approach for the evaluation of strength. The approach is widely used in medicine (81) and sports (82) as it delivers critical information on men's conditions and athletes' physiological characteristics (83). It was suggested that HGS is affected by BMI (84, 85), lean body mass (69, 86), and possibly by athletes' body weight (87). In the current study, we have used athletes' body weight as a predictor of HGS and found that the relationship is moderated by athletes' age and years of training. Assuming that with skills in martial arts, the change of handgrip strength could be expected, we have suggested that the relationship is moderated by athletes' age and years of training. While numerous studies involve sports disciplines, more information is needed for athletes training in martial arts. The presented study is devoted to filling the gap, at least in some martial arts utilizing moderation analysis (55), exploited in psychology (56, 57) and biological sciences (88), but also in sports (62, 66). Such a method has yet to be exploited to evaluate the relationships between variables explaining HGS.

Simple moderation analyses revealed that athletes' body weight impacts HGS. The athletes' ages and years of training serve to moderate the relationships. According to our findings and Johnson-Neyman statistics (Figure 2), athletes' body weight affects HGS until their 52nd year. Similarly, years of training moderated the body weight-HGS relationship until 39 years of training (Figure 3); however, years of training explained 46% while age 50.5% of HGS variance what makes athletes age a better moderator of the relationships between body weight and HGS. Although unrelated to the relationship between body weight and HGS, our results are congruent with the data presented for sprint, middle- and long-distance runners (89), where the linear drop in performance was observed up to 70 years old compared to 52 in the current study. Smaller age-related declines in cycling performance than in running and swimming have been documented (90). However, a significant performance increase is observed for master athletes (91), indicating that progress limits are not achieved, and physiological limitations of age could be overcome with training. It was also documented that young athletes training in long, high and triple jump achieve their best results at the beginning of their twenties (92). Interestingly, the mean peak age and performance progression in track and field athletes established based on competitions conducted between 2002 and 2016 was typically 25–27 years of old, but somewhat higher for marathon and male throwers (~28–29 y) (93). In general, performance decline in athletes is assumed to occur around 40 years. Anyway, the decline in performance seems to depend on sports activity modes of locomotion, event duration, and participant gender (94). Following the reasoning, our results fit between the two limits and may reflect the specificity of the martial arts we investigated.

Following the relationships evaluated between body weight and HGS utilizing moderation by age, the results of similar moderation with years of training as a moderator become obvious. Assuming that, in general, martial arts athletes start training somewhat between 10 and 20 years old, it is not surprising that the moderation is significant till 39 years of training, which seems to correlate with age performance. An exciting outcome of the study is that the older the athletes are (or the longer they train), the lower the effect of body weight on HGS, which seems to correlate with the notion that the younger the athlete, the more they will benefit from a relatively more extended preparation phase (https://trainforskills.pl/adaptacja-anatomiczna/) and the older youth athletes also need to train more heavily than their younger colleagues (95). Furthermore, the presented data indicates that putative loss of body weight may have an adverse effect on performance, as shown in martial arts (96).

Recently, we have demonstrated that skills expressed in belts used in four martial arts may be associated with HGS (97); however, the differentiation could have been more apparent as only the athletes with the highest grades were distinguished from the other partitioners. Thus, we have suspected that the relationship between skills and HGS is more complicated and could be moderated by other factors. Among the candidate variables, the athletes' age and years of training were considered and employed in moderation analysis. Instead of simple moderation, it was revealed that moderated moderation was evaluated. The moderated moderation model involving interaction between skills, age, and years of training allowed for the explanation of an additional 7.7% variance of HGS. Still, the model was capable of about 53.7% of the variance of HGS, suggesting that there have to be more factors explaining the relationships between skills and HGS. It should be stressed that triple interaction (skills x age x years of training) is stated for the additional 12.9% of the variance. The current results are congruent with those demonstrating that fine motor skills evaluated between skilled and non-skilled persons affected muscle strength, demonstrating a putative linkage between skills and HGS (98). Moreover, conditional skills*age interaction on HGS was significant until 12.25 and after 44.8 years of life.

Similarly, it was shown that sports participation in adolescents increased strength parameters remarkably compared to non-athlete adolescents (99). An interesting finding of the analysis is that older athletes do not seem to improve HGS if they train longer and that the change is unrelated to skills. However, young athletes(up to 36 years old) may improve HGS during the first 16 years of training. Afterwards, the decline in HGS is observed independently of age and skills. The data presented indicates that younger athletes have better chances for increased performance in martial arts with years of training; however, there is a limited time, which is probably related to physiological changes that develop with ageing.

The tested moderation analyses were significant, indicating that the predictor could explain at least part of the variation in the outcome. However, in general, the level of explanation varied between 40 and 50.5%. Furthermore, the involvement of moderators increased the values from 2.4 to 7.7%. Thus, the presented moderations were sufficient to explain an additional fraction of variation, resulting in up to 57.2%. Other factors not involved in the study, i.e., BMI and height, should be considered to fit the results better. The other vital suggestion is implementing more sophisticated statistical approaches, such as structural equation modelling (SEM), mainly used in psychology and biological sciences (100-103) to have more variables explaining HGS and illustrate their relationships, effects, and significance. The presented study forms a background for the models explaining HGS and possibly useful for trainers in martial arts.

Conclussions

The presented study has revealed interesting relationships between body weight and HGS moderated by age and years of training not previously published in the literature related to martial arts. Additionally, we have shown how skills affect HGS in a person's life and how relationships change with age and training. The implication of our study could be helpful for trainers in giving a rationale for explaining HGS as a factor reflecting human strength and physiological condition.

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Data Availability Statement: Details regarding data availability can be asked from the author.
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