Original paper

Handgrip strength and body mass index in Polish and Croatian female university students of preschool and primary education

Siła chwytu oraz względna masa ciała studentek edukacji przedszkolnej i wczesnoszkolnej z Chorwacji i Polski

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Key words: young adults, body mass index, grip strength.

Słowa kluczowe: młodzi dorośli, wskaźnik masy ciała, siła chwytu.

Abstract

Introduction: Recent years have seen a decrease in muscle strength, which may lead to sarcopaenia, and may be associated with a risk of diseases of affluence and premature mortality. Grip strength measurement in young adults is particularly important for teachers because it determines how effectively they are able to perform their duties.
Aim of the research: To determine the relationship between handgrip strength (HGS) and normalised grip strength (NGS) and body mass index (BMI) in female university students.
Material and methods: The study participants comprised 231 young women from Poland and Croatia. Their handgrip strength was measured, and their BMI and NGS were calculated. Differences between groups of students from Poland and Croatia were determined using Student's *t*-test. The relationships between HGS and NGS and somatic traits and BMI were assessed using the Pearson's correlation coefficient. Differences between BMI categories were assessed using one-way ANOVA.
Results: Mean HGS among the participants from Poland and Croatia equalled 29.9 ±4.75, and mean NGS equalled 0.49 ±0.13. Both HGS and NGS among all participants from Poland and Croatia showed a statistically significant correlation with body height, body mass, and BMI. In terms of HGS and NGS relative to BMI categories, women with overweight or obesity had the highest HGS, while women with underweight obtained significantly lower results ($F = 5.152$, $p = 0.006$). The opposite correlations were observed for NGS ($F = 51.858$, $p < 0.001$).
Conclusions: The observed significant correlations between NGS and BMI suggest that NGS is an important biomarker of health.

Streszczenie

Wprowadzenie: W ostatnich latach obserwuje się regres siły mięśniowej, która może prowadzić do sarkopenii oraz wiązać się z występowaniem ryzyka zachorowalności na choroby cywilizacyjne oraz przedwczesną śmiertelnością. Pomiar siły chwytu u młodych dorosłych nabiera znaczenia w przypadku pracy nauczyciela, dla którego siła ręki warunkuje efektywne wykonywanie swoich obowiązków.
Cel pracy: Określenie zależności pomiędzy siłą mięśniową (HGS) oraz względną siłą mięśniową (NGS) badanych studentek a względną masą ciała (BMI).
Materiał i metody: W badaniach wzięło udział 231 młodych kobiet z Polski i Chorwacji. Ocenie poddano siłę chwytu. Obliczono względną masę ciała (BMI) oraz względną siłę chwytu. Do określenia różnic grupowych między wynikami studentek z Polski i Chorwacji wykorzystano test *t* Studenta. Zależność między HGS i NGS a cechami somatycznymi oraz BMI oceniono za pomocą korelacji Pearsona. Do oceny różnic między kategoriami wskaźnika BMI wykorzystano jednoczynnikową analizę wariancji ANOVA.
Wyniki: Badane kobiety z Polski oraz Chorwacji osiągnęły średnią wartość siły średniej 29.9 ±4.75 oraz siły względnej 0.49 ±0.13. W przypadku zarówno siły średniej, jak i siły względnej dla ogółu badanych z Polski i Chorwacji zaobserwowano występowanie istotnej statystycznie korelacji z wysokością ciała, masą ciała oraz BMI. W analizach siły i siły względnej w odniesieniu do kategorii wskaźnika BMI stwierdzono, że kobiety charakteryzujące się nadwagą lub otyłością uzyskały najwyższe wskaźniki HGS, a osoby z niedowagą osiągały istotnie niższe rezultaty ($F = 5.152$, $p = 0.006$). Odwrotne zależności uzyskano w przypadku wartości siły względnej ($F = 51.858$ i $p < 0,001$).
Wnioski: Obserwacje istotnych zależności pomiędzy NGS a BMI mogą świadczyć o tym, że ocena NGS jest ważnym biomarkerem zdrowia.

Introduction

The increasingly prevalent decrease in muscle strength and muscle mass in society is considered a risk factor for diseases of affluence, alongside physical activity and excessive body mass [1–7]. The decrease may lead to sarcopaenia, i.e. a general and progressive atrophy of skeletal muscles and loss of strength that impacts quality of life and causes physical unfitness or even death [4]. The decrease in muscle strength primarily concerns seniors; however, it is observed increasingly in adults or even children and youths [8]. Multiple findings from the last 20 years indicate that sarcopaenia is not associated exclusively with ageing [4, 8, 9] but may also have its origins in early life and affect an individual's functioning throughout adulthood. This necessitates an early and effective intervention in this respect [8]. Subject literature also indicates that causes of sarcopaenia should be sought beyond ageing [4, 8, 9]. More or more young people need to undergo observation and prophylaxis in this respect. From the epidemiological perspective, it is recommended the peak grip strength obtained in early adult life be increased [10, 11].

Muscle strength is defined as the maximum amount of force a muscle can produce in a single effort [12]. It determines the ability to perform physical effort, which makes it an important component of physical fitness and a major factor for the satisfactory performance of everyday activities, both at work and during free time [12]. A correct level of muscle strength is also thought to be associated with functional independence and a high quality of life [13]. Furthermore, muscle strength is related to a lower prevalence of cardiometabolic risk factors and lower frequency of cardiovascular disease (CVD) events [14, 15]. Conversely, low muscle strength is considered an important risk factor for loss of health [16–18].

One of the most common methods of assessing muscle strength is grip strength measurement, considered a risk-stratifying method for all-cause death, cardiovascular death, and cardiovascular disease [13]. Low hand grip strength (HGS) is related to a risk of morbidity and premature mortality in a population [19–21]. Consequently, subject literature indicates a need to assess HGS for diagnostic purposes not only in seniors, but also among groups that to date have not shown a general decrease in strength [4, 13]. Both genders display a similar pattern of muscle strength growth up to puberty; from puberty onwards, men undergo a sharp increase in strength. In women, strength develops in a more linear pattern than in men, with the development reaching its peak between the age of 26 and 42 years. Regressive changes in muscle strength also appear considerably earlier in women than in men [9]. A group of young adults is an important point of reference, firstly for the purposes of analysing the changes of development of strength, and secondly due to the relationship between strength and indicators of health and quality of life. Early assessment of grip strength may also significantly contribute to sarcopaenia prevention.

Muscle strength is determined by both genetic and environmental factors. Individuals with low body mass showed a much lower strength than normal-weight individuals [22]. Conducted observations indicate a clear relationship between somatic traits and HGS. A positive correlation was found between body mass and body mass index (BMI) and between body mass and HGS [20, 23–28]. On the other hand, muscle strength is an important regulator of fat-free mass (FFM) and resting metabolic rate, which significantly affect weight management [12]. Environmental factors that show a significant relationship with muscle strength are lifestyle and physical activity [15, 29]. These factors indicate the importance of monitoring adults, especially women, including university students, who display a lowered level of daily physical activity due to increased sitting time, usually spent studying and using social media. This may lead to an increase in body mass [30–32] and a slower increase in muscle strength, as well as to an early onset of regressive changes in strength among young women [15, 29].

Preschool and early school young female university students will become teachers in the future. On the one hand, these women represent societal potential, and on the other, they will have a considerable influence on the shaping of healthy habits in their students. Furthermore, as part of their occupation, they will have to perform many manual tasks requiring a high level of precision and dexterity, which depend on both hand-eye coordination and a strong grip. HGS is a critical source of force for work-related activities, and it contributes to the performance of tasks involving hand-eye coordination, which is crucial for skills that allow children and their teachers to grasp, grip, and manipulate. A stronger HGS indicates a firmer grasp or grip [30–33]. The observation of muscle strength is particularly important considering that since 2000 a decline in adult HGS has been noted, especially in most high- and upper-middle-income countries, which also leads to a decline in the functional strength capacity and health of society [29].

Aim of the research

The aim of this study is to determine the relationship between HGS and normalised grip strength (NGS) and BMI in female university students from Poland and Croatia, who are future preschool and early school teachers.

Material and methods

Material

The study was cross-sectional. The participants comprised 231 young women who were university students of preschool and primary school education

from Poland and Croatia. Of these, 81 were recruited from the University of Zagreb Faculty of Teacher Education (Croatia), and 151 were recruited from the Jan Kochanowski University of Kielce (Poland) Faculty of Education and Psychology. The mean calendar age of all participants was 21.9 ±1.61 years. The Poles were slightly older (22.6 ±1.26 years) than the Croatians (20.6 ±1.61 years). All individuals who agreed to participate and who had signed the consent took part in the research. Exclusion criteria included a medical and clinical diagnosis of a major systematic disease.

Prior to the study, consent for research was obtained from the Committee of Bioethics at Collegium Medicum, Jan Kochanowski University of Kielce, Poland, No. 57/2021.

Methods

The HGS maximal isokinetic grip force task is a practical, feasible, and scalable functional measure of overall strength for clinical and population screening and surveillance [34]. The use of HGS measurement in a population study was primarily motivated by its high effectiveness and reliability and a relatively simple research procedure.

The HGS measurement was performed according to the ACSM procedure [12] among students from both countries. Each participant underwent the measurement in a standing position, gripping a dynamometer with her dominant hand, with the other arm kept by the side. The measurement was repeated after 10 min. The better of the 2 results was taken into account in the assessment. Furthermore, NGS was calculated by comparing each participant's HGS to her body mass. This allowed us to achieve better accuracy when comparing individuals with different body sizes and to focus on muscle quality, rather than muscle quantity [35]. The measurement was performed using a hand dynamometer with adjustable grip (Gima, Smedley Hand Dynamometer).

Body height was measured barefoot, with accuracy to 0.1 cm, and body mass was measured with accuracy to 0.1 kg. Weight and body height measurements were used to calculate BMI (kg/m^2). In accordance with the WHO classification of BMI, the participants were then categorised into 3 groups: underweight, BMI ≤ 18.5 kg/m^2; normal weight, BMI 18.5–24.9 kg/m^2; and overweight or obesity, BMI ≥ 25 kg/m^2.

The assessment of strength and differences in strength depending on BMI took into account both groups of students jointly. For the purposes of the assessment of the relationship between HGS, NGS, and BMI categories for all participants from Poland and Croatia, a subgroup of students with normal values of body mass relative to height (67.97%) was distinguished. Overweight and obese students constituted over one-fifth (21.65%), and underweight students constituted 10.39% of all study participants.

Statistical analysis

Statistical analysis was performed once the measurements were obtained. Mean ± standard deviation, median, and percentiles were used to present the descriptive data. Group differences in body mass, body height, BMI, HGS, and NGS between students from Poland and Croatia were determined using Student's *t*-test. The relationships between HGS and NGS and somatic traits and BMI were assessed using the Pearson's correlation coefficient. Differences between BMI categories were assessed using one-way ANOVA. Statistical significance of ≤ 0.05 was assumed for all performed statistical analyses.

Results

Students from Croatia were taller than students from Poland (Table 1). Otherwise, no significant differences were found in body mass, BMI, HGS, or NGS. The 2 groups were combined for the subsequent analyses (Table 2).

A statistically significant correlation was found between both mean HGS and NGS among all participants from Poland and Croatia and body height, body mass, and BMI. NGS showed a negative correlation because an increase in the value of NGS (HGS/BM) involves a decrease in body height, body mass, and BMI (Table 2).

Table 1. Mean values and differences in BH, BM, BMI, HGS, and NGS between university students from Poland and Croatia

Variable	Students from Poland and Croatia combined (SD)	Students from Poland *N* = 150	Students from Croatia *N* = 81	*t*	*P*-value
BH [cm]	165.3 (6.55)	164.2 (5.72)	167.4 (7.43)	–3.679	< 0.001*
BM [kg]	62.8 (12.35)	61.7 (11.94)	64.9 (11.94)	–1.927	0.0552
BMI [kg/m^2]	22.9 (3.98)	22.9 (4.06)	23.1 (3.86)	–0.435	0.663
HGS [kg]	29.9 (4.75)	29.7 (3.98)	30.1 (5.94)	–0.608	0.543
NGS (HGS/BM)	0.49 (0.13)	0.50 (0.15)	0.48 (0.15)	1.606	0.110

**Statistically significant difference. BH – body height, BM – body mass, BMI – body mass index, HGS – handgrip strength, NGS – normalised grip strength.*

Table 2. Correlation between HGS, NGS, and somatic traits and BMI in university students from Poland and Croatia combined (*r* value)

Variable	BH [cm]	BM [kg]	BMI [kg/m²]
HGS [kg]	0.296*	0.349*	0.228*
NGS (HGS/BM)	–0.191*	–0.638*	–0.623*

**Statistically significant difference. BH – body height, BM – body mass, BMI – body mass index, HGS – handgrip strength, NGS – normalised grip strength.*

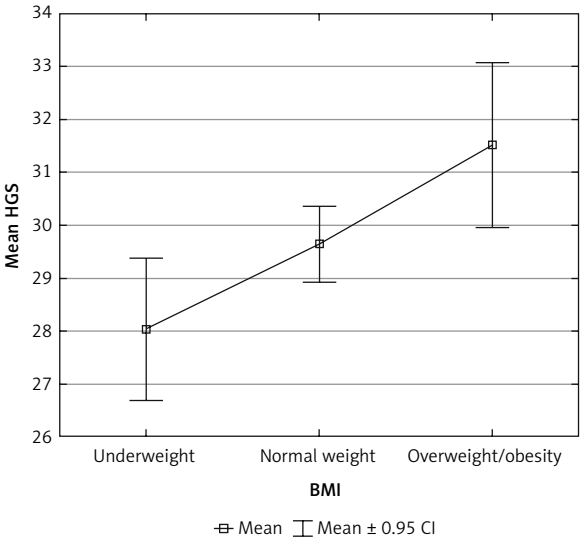

Figure 1. Mean HGS in groups of women with underweight, normal weight, and overweight or obesity

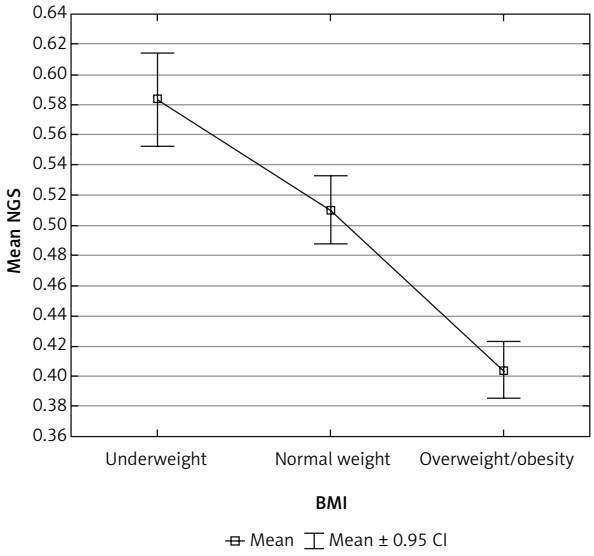

Figure 2. Mean NGS in groups of women with underweight, normal weight, and overweight or obesity

Table 3. HGS according to BMI in study participants

BMI category	*N*	HGS		Min.	Max.
		Mean	SD		
Underweight	24	28.0	3.193	22	34.5
Normal weight	157	29.6	4.572	16.5	41
Overweight and obesity	50	31.5	5.475	21	47

Table 4. NGS according to BMI in study participants

BMI category	*N*	NGS		Min.	Max.
		Mean	SD		
Underweight	24	0.58	0.074	0.43	0.69
Normal weight	157	0.51	0.141	0.26	1.97
Overweight and obesity	50	0.40	0.066	0.27	0.55

The assessment of HGS and NGS in relation to the aforementioned BMI categories showed that women with overweight or obesity obtained the highest HGS results, whereas women with underweight obtained the lowest results; the differences were statistically significant ($F = 5.152$, $p = 0.006$) (Table 3, Figure 1). The opposite correlations were observed for NGS ($F = 51.858$ and $p < 0.001$) (Table 4, Figure 2).

Discussion

A detailed analysis of the HGS measurements conducted by different authors is very difficult due to different research methodologies – in particular, the inconsistent allocation of participants into age groups. The mean HGS result (29.9 kg) obtained in our study was better than that obtained in recent observations (Table 5), with the exception of a study by Bahat *et al.* [36], in which a group of women aged 18–31 years obtained a mean result of 33.1 kg [37–41]. A comparison between the results of this study with those obtained by Dodds *et al.* [9] based on a cross-sectional analysis of 12 studies conducted in the UK leads to interesting conclusions. Dodds *et al.* used the analysis to establish normative values for grip strength according to age and gender. Mean HGS was 28.4 ±5.1 kg ($N = 463$) for 20-year-old women and 30.6 ±5.6 kg ($N = 870$) for 25-year-old women. Taking into account the age of the Polish and Croatian participants of this study (21.9 years), the HGS results ($x = 29.9$ kg) achieved in our research can be considered similar to those of the study by Dodd *et al.* (Figure 3).

Another important issue is determining the threshold of insufficient muscle strength in women. Dodds *et al.* [9] propose using the method of 2 standard deviations subtracted from the arithmetic mean

Table 5. HGS results obtained in this study compared to selected recent studies conducted in various countries

Research	Year of publication	*N*	Age of participants		HGS [kg]	
			Mean	Range	Mean	SD
Lopes *et al.* (Brazil) [37]	2017	40	39	29.3–49.5	26.9	4.1
Garcia-Hermoso *et al.* (Columbia) [5]	2020	1103	20.59	n/a	24.04	4.95
Das, Dutta (India) [38]	2015	200 (F + M)		18–23	20.07	4.5
Bansole *et al.*, (India) [26]	2014	45	19.28	n/a	28.91	3.15
Ingrova *et al.* (Czech Republic, Slovakia) [39]	2017	191	21.76	18–35	26.6	5.4
Cao *et al.* (China) [40]	2021	599	18.7	16–23	17.7	4.3
Yoo *et al.* (South Korea) [41]	2017	199	n/a	19–24	24.61	4.69
		140	n/a	25–29	24.12	4.18
Bahat *et al.* (Turkey) [19]	2016	114	25.9	18–39	33.1	5.3
Dodds *et al.* (UK) [9]	2014	463	20	n/a	28.4	5.1
		870	25	n/a	30.6	5.6
Liao (Taiwan) [20]	2016	200	20.1	n/a	37.28	9.15
This study (Poland, Croatia)	2021 (year of measurement)	231	21.9	19-26	29.88	4.75

as the cut-off point for a given population or applying a more sensitive indicator, i.e. 2.5 standard deviations subtracted from the mean. In the case of the Polish and Croatian university students, the cut-off point equalled 20 kg for 2 SD and 18 kg for 2.5 SD. For the former threshold, 2.60% of the participants (6 individuals) showed low muscle strength, and for the latter, 1.30% (3 individuals). The results obtained in our research indicate that as early as at the age of 20 years, some young women are at risk of sarcopaenia, which is a disorder that considerably impacts the ability to perform basic everyday tasks and lowers the quality of life. This should encourage epidemiologists to analyse HGS further in the context of sarcopaenia by taking into account young women from different environments and standardising age groups (Figure 3).

Most available studies report a positive correlation between HGS and BMI, which matches the results obtained in our study and studies conducted by other authors [20, 25, 26, 42–45]. Conversely, Lad *et al.* [46] found the highest grip strength in underweight females (low BMI) and the lowest in overweight subjects. Dhara and Sengupta *et al.* [24] recorded very weak and statistically insignificant positive correlations between grip strength and BMI. Table 6 compares the correlations between HGS and BMI categories observed in this study and selected studies conducted by other authors.

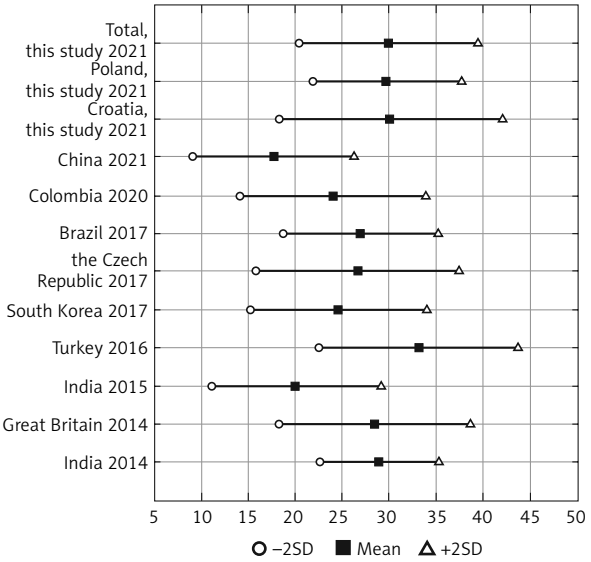

Figure 3. Mean HGS in Polish and Croatian university students compared to studies conducted by other authors

The observed positive correlations in our study between BMI and HGS may be linked to the relationship

Table 6. Mean HGS according to BMI categories in this study and studies by other authors

BMI category	Mohdrazip & Azwani Mohd Shukri (2020) [47] Malaysia, *N* = 102		Das & Dutta (2015) [38] India, *N* = 200		This study (2021), Poland and Croatia, *N* = 231	
	HGS, mean	HGS, SD	HGS, mean	HGS, SD	HGS, mean	HGS, SD
Underweight	21.47	3.23	16.4	n/a	28.0	3.19
Normal weight	22.89	3.49	20.0	n/a	29.6	4.57
Overweight/obesity	23.31	3.32	19.0	n/a	31.5	5.47

between body height and handgrip strength. Tall persons usually have long limbs, which translated into a higher handgrip strength than in short persons [23, 39, 44]. Research on HGS also indicates a low correlation between fat mass and handgrip strength [39].

Because both physical fitness and health are directly mediated by the proportion of strength relative to body mass, we decided to normalise grip strength according to body mass. Unfortunately, most studies analysing NGS focus on middle-aged adults and adults of other ages, which makes it difficult to compare the results obtained by the young women in this study with the results of other studies. The women from Poland and Croatia obtained an NGS value of 0.49 ±0.13, which is higher than those obtained by young women from Columbia (NGS 0.42 ±0.09) [47].

According to Garcia-Hermoso *et al.* [5], NGS may be an important modifiable lifestyle factor for the assessment of CVD risk, alongside physical inactivity, body composition, and healthy dietary patterns. The values of NGS are a very accurate indicator of the thresholds and risk categories in metabolic syndrome (MetS) [5]. The findings of Dulac *et al.* [48] showed that handgrip strength divided by body weight correlated positively and significantly with functional capacity in postmenopausal women. Subject literature increasingly suggests that monitoring NGS should be included in clinical settings for the identification of people at high risk of cardiometabolic disease and MetS [5]. A comparative study conducted by Peterson *et al.* [49] among middle-aged adults (50.0–64.9 years) and older adults (≥ 65 years) from China (n = 6030) and the US (n = 4544) showed that low NGS may be a biomarker for cardiometabolic disease and physical disabilities. Lawman *et al.* [50], based on research conducted among adults aged 47.5 years (n = 4221), reported significant correlations between NGS and lower systolic blood pressure, triglycerides, plasma insulin, and glucose and higher high-density lipoprotein cholesterol in males and females, which indicates a relationship between increased NGS and a better profile of cardiovascular health biomarkers.

The participants of our study who had underweight and normal weight obtained higher values of NGS than the participants with overweight and obesity. This substantiates the importance of acknowledging the role of body composition on strength capacity and incorporating normalised values based on BMI, body height, and body mass in analyses of muscle strength conducted in the context of sarcopaenia and the tendencies and changes in its ontogenesis [51].

Several limitations of this study should be mentioned. The study was conducted among a relatively small population that was not representative of all young women. Moreover, the study incorporated a limited number of variables. Future research is planned to also include an assessment of other manifestations of muscle strength variables related to body composition, physical activity, and lifestyle.

On the other hand, one of the strengths of this study was its international character – it was conducted in 2 EU member states. Furthermore, the studied group was uniform in terms of age, gender, education, and perspectives for professional development, which helped to determine the state of muscle strength in young university students in comparison to studies conducted by other authors and the participants' BMI.

Conclusions

In comparison to women from other countries, the young adult women from Poland and Croatia obtained relatively high HGS results, which may indicate their good health and a higher likelihood of delayed decrease in muscle strength in ontogenesis and sarcopaenia in the future. The high values of HGS may also contribute to the participants' professional effectiveness as early school and preschool teachers and efficient social functioning. The observed significant correlations between NGS and BMI suggest that an assessment of NGS should be part of medical diagnostics in young adults, as an important marker of cardiometabolic disease and MetS.

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Conflict of interest

The authors declare no conflict of interest.

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