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The Influence of Age and Type of Force on Muscle Strength Capabilities in Women

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The aim of this study was to assess handgrip and 5 other types of force in 52 women and to determine if handgrip force reflected general upper limb force capabilities correlated with age. The women were divided into subgroups according to age: 20–25, 45–50 and 55–65 years. Maximum forces of the right upper limb were measured in 6 types of force activities. In most tests the values of force showed statistically significant differences between the 20–25 group and the groups aged 45–50 and 55–64 years. The results did not show any differences related to age or to force activities that involved the small muscles of the forearms and hands. Thus handgrip force cannot always be considered an indicator of total force capabilities.

muscle strength ageing women

1. INTRODUCTION

Force capabilities are significant not only in everyday activities [1]. Some upper limb activities such as handgrip, turning the forearm or flexion/extension of the upper limb are important in daily activities as well as in work activities such as manual work, assembly work, packing or lifting [2]. Since many work tasks require adequate muscle strength, if workers' force capabilities are too low, they can develop musculoskeletal disorders [3].

Maximum force capabilities depend on the type of force and on upper limb posture during force exertion [3]. Gender is important, too [4]. Men and women have different force capabilities, with women's maximum force capabilities between 50% [5] and 78% [6] of men's capabilities. The age factor cannot be underestimated, either [7]. Ageing involves a progressive decline in neuromuscular functions and performance, with a decrease in muscle mass and morphology and concomitant reduction in muscle strength [8, 9].

Muscle strength peaks between the ages of 20 and 35, and then decreases between 35 and 50 years, with much more rapid changes after the age of 65 [10]. Hanten, Chen, Austin, et al. [7] and Balogun, Adenola and Akinloye [5] showed similar changes in men's handgrip force in a group of 30–50-year-olds. Other researchers found a decline in strength in persons over 60 from 14 to 45% compared with a group of 20-year-olds [11, 12, 13, 14, 15]. According to Frontera, Hughes, Fielding, et al. force capabilities decreased essentially after the age of 60, at ~1.5–2.5% per year [16].

The mean age of the population is increasing [17], which means the working population will be older too. Decrease in strength in elderly workers proved by many studies [7, 18] can increase their load, unless it is considered in designing the work process. The loss of functional ability resulting from decreased muscle strength can decrease

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the quality of life by making routine activities more difficult; it may even lead to physical disability [8, 19, 20]. A study on age-related muscle strength loss is critical to understanding how older workers can maintain muscle strength and physical fitness, and also to learning how work processes for older workers should be designed.

Since workers' older age and their decreased capabilities should impose on employers a modification of workstations, data on those capabilities are important [21]. Upper limbs are involved in most work activities; therefore, upper limb strength capabilities of older workers are crucial [21].

To perform simple manual work a worker must be able to perform basic tasks, such as hand gripping, lifting and transferring. Most studies on strength capabilities focus on handgrip strength [18, 22, 23]. According to some studies, handgrip strength correlates well with total body muscle strength [8, 24, 25].

Roman-Liu and Tokarski proved that maximum force capabilities depended both on upper limb posture and on the type of exerted force, and that upper limb posture influenced the values of force depending on the type of force [3]. It can be supposed that not only posture but also age influence various types of force activities in different ways. Muscle strength declines with age [26] and the negative influence of ageing on muscle function can be different for different muscle groups [10, 14]. Most studies were performed for men, while women have lower force capabilities, which makes them more vulnerable to forces at the workplace; therefore, there is a greater need to study women.

The aim of this study was to assess strength capabilities in a population of women regarding handgrip and five other types of force, in three age groups, and to determine if handgrip force reflected general upper limb force capabilities in relation to age.

2. METHODS

2.1. Subjects

The study was performed on three groups of healthy working women randomly selected according to an age criterion. A homogeneous group of 10 women aged 20–25 years was the reference group. Women aged 45–50 (n = 21) and 55–65 (n = 21) also participated in the study.

Women with any musculoskeletal disorders were excluded. Physical activity, social status, training or family status were not considered. Table 1 lists the characteristics of the groups.

2.2. Measurement Procedure

Measurements took place between 9 a.m. and 12 noon. First, the participants warmed up with low-intensity physical exercise, a 5-min warm-up of the upper limbs and hands connected with the tested activities. Standardized instructions were given to familiarize each participant with the device and the measurement procedure.

Maximum forces of the right upper limb during six types of force activities were measured: handgrip and lateral pinch force, pronation and supination of the forearm, and flexion and extension of

TABLE 1. Characteristics of Groups of Subjects

Parameter	Age Group	*M*	*SD*	Min	Max
Age (years)	A	22.24	0.37	21.5	22.9
Age (years)	B	47.79	1.67	45.1	50.4
Age (years)	C	59.51	3.26	55.3	65.0
Body mass (kg)	A	63.47	11.80	48.1	86.9
Body mass (kg)	B	67.06	9.91	53.3	94.3
Body mass (kg)	C	70.29	11.62	50.3	92.2
Body height (cm)	A	172.10	6.30	164.0	184.0
Body height (cm)	B	161.33	5.48	153.0	172.0
Body height (cm)	C	161.76	3.97	157.0	170.0

Notes. A—20–25-year-olds, B—45–50-year-olds, C—55–64-year-olds.

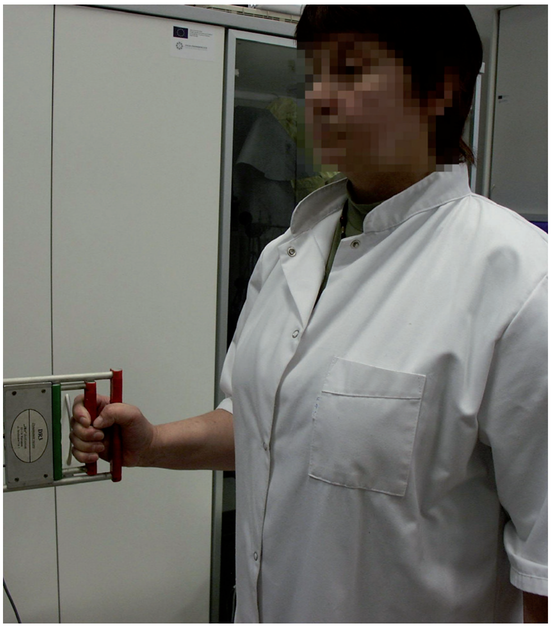

Figure 1. Measuring handgrip force.

Figure 2. Measuring pronation and supination torque.

the forearm and the arm. Each randomized measurement was performed twice with a minimum of a 5-min break between each measurement. The higher value of the two maximal force exertions was the definitive measurement.

Three stands with a system for measuring maximum force were used. During handgrip and lateral pinch force measurements, the participant stood with her trunk and head straight. The angles of the upper extremity were 0° for the arm, 90° for the elbow and 0° for the angle between the forearm and the hand (Figure 1).

During pronation/supination measurements, the participant sat with her trunk and head straight. The angle between the hips and the knees was 90°. The angles of the upper extremity were 0° for the arm, 90° for the elbow and 0° for the angle between the forearm and the hand (Figure 2).

A frame construction for measuring forearm and arm muscles was designed especially for this study. Its purpose was to ensure the participants' proper posture and to stabilize the neighbouring parts of the body.

Each participant stood with her trunk and head straight. The angles of the upper extremity when the muscle torques of the arm were measured were 90° for the arm, 90° for the elbow and 0° for the hand (Figure 3). The angles of the upper extremity during the measurements of the muscle torques of the arm were 0° for the arm, 90° for the elbow and 0° for the hand (Figure 4).

2.3. Measurement Equipment

Forces and torques were measured with three measurement devices from JBA Zb. Staniak (Poland): tensometers, an analogue–digital converter, a personal computer and special software. The devices were calibrated every day before and after the measurements.

Each measurement system was built of 1000-Ω tensometers combined into a full Wheatstone bridge. The maximal error of the measurement system was under 1%. The system was equipped with one fully integrated amplifier. A 12-bit analogue–digital converter made a sampling rate of 100 Hz possible; the converter was connected through a serial port to the personal computer.

A dynamometer measured handgrip force of up to 1200 N and lateral pinch force of up to 200 N. Pronation and supination torques were measured with a torque meter for static conditions with a range of up to 50 Nm. Force and its arm were measured to assess the torques of flexion and extension of the elbow and the arm. The dynamometer measured force of up to 2000 N.

(a) (b)

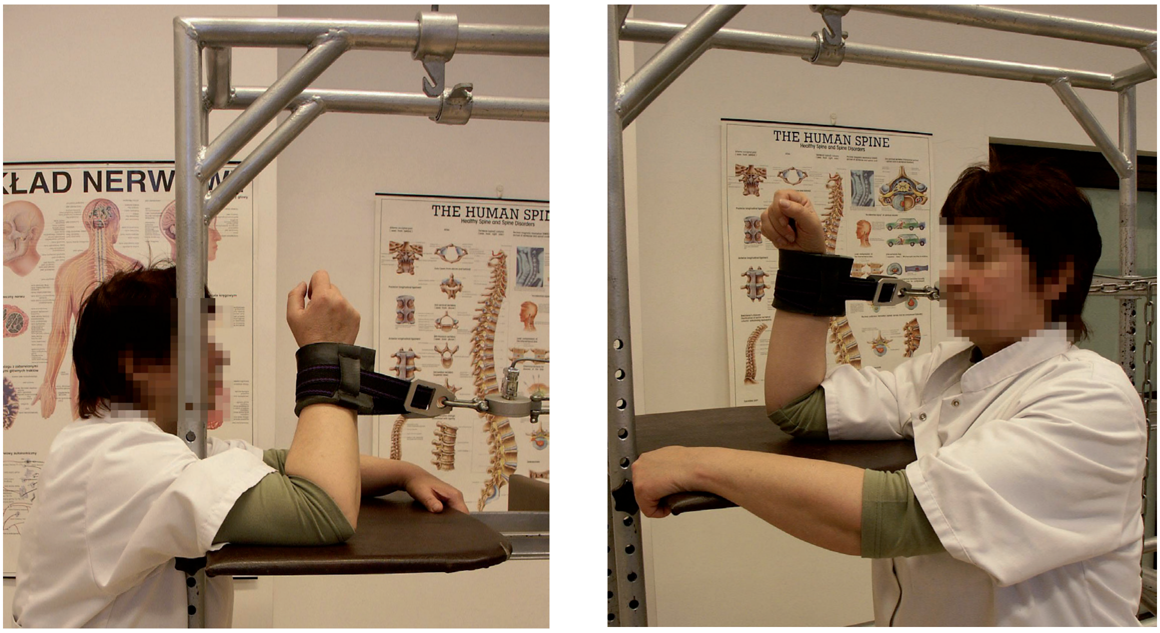

Figure 3. Measuring forearm flexion and extension.

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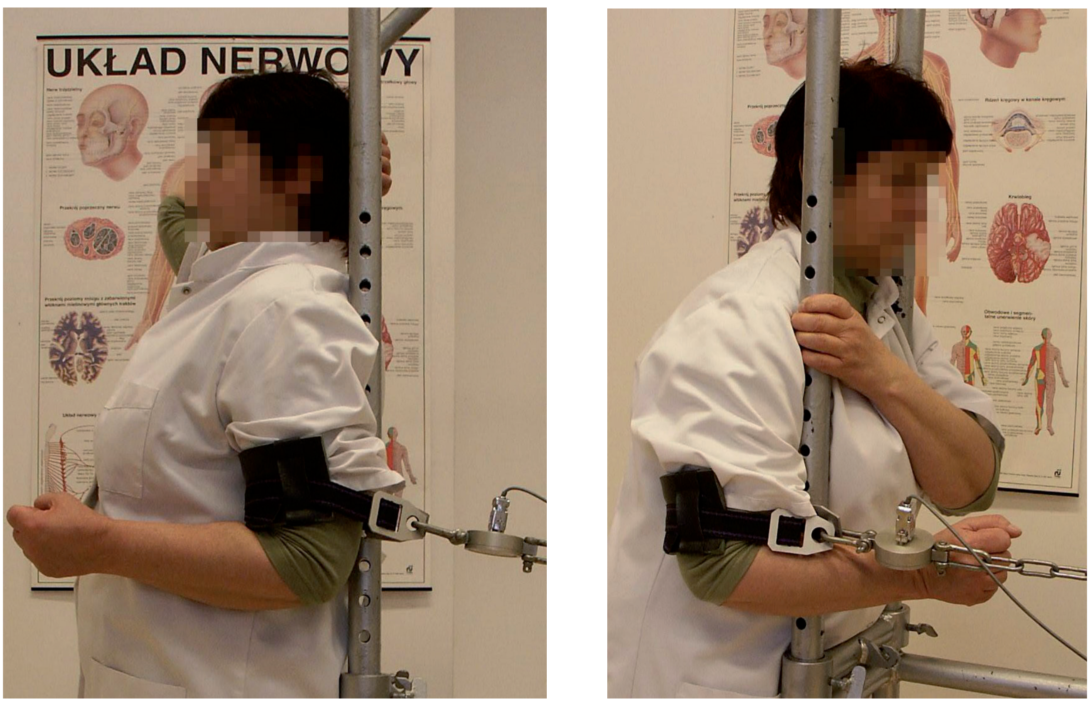

Figure 4. Measuring arm flexion and extension.

2.4. Analysis of Results

The analysis of the results aimed to establish the differences between the values of maximum forces related to six types of force activities, and to age. It was also to explore if the type of force activities influenced age-related differences in force. The decrease in force was calculated in the 45–50 and 55–65 groups as a percentage of the reference group of the 20–25-year-olds. The correlation of handgrip force with other types of forces was also analysed.

Data was analysed with Statistica version 6.0. Differences between groups were examined with an analysis of variance (ANOVA) after the necessary requirements were confirmed with the Leven test [27]. The effect of age on the values of the force of flexors and extensors of the elbow and the shoulder was also determined by analysing the correlation between the values of those parameters and age. The nonparametric Spearman correlation coefficient was used to find if handgrip force correlated with other forces and if age correlated with each measured force.

3. RESULTS

Figure 5 shows maximum force capabilities for handgrip and lateral pinch. The mean value of lateral pinch force was 59–66 N for the 55–64- and the 20–25-years-olds, respectively. Handgrip force also decreased with age; mean values were 335–415 N. The values for lateral pinch in the three age groups were not statistically significant. However, in handgrip force there were statistically significant differences between forces obtained for the 55–64-year-olds, and the 45–50- ($p = .017$) and 20–25-year-olds ($p = .008$).

For supination and pronation the values of torque were very similar in the 45–50 and 55–64 groups (Figure 6). However, there were also statistically significant differences between those two groups and the group aged 20–25 years. For supination the differences were statistically significant for the 45–50 group ($p = .026$) and the 55–64 group ($p = .01$). For pronation the values were $p = .035$ and $p = .045$, respectively. The mean values were 5.5–6.8 Nm for pronation and 5.7–7.2 Nm for supination.

The values obtained for elbow extension showed no differences related to age; the mean values

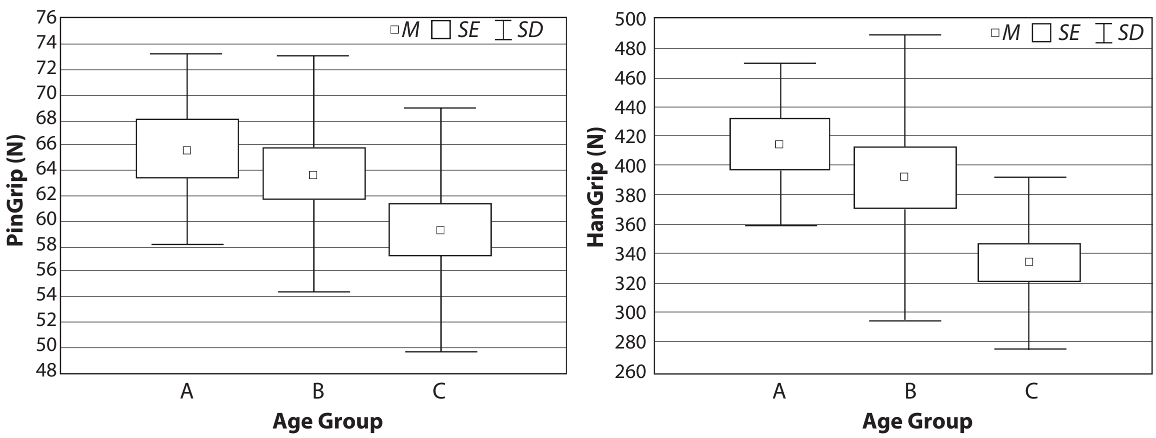

Figure 5. Maximum forces during lateral pinch (PinGrip) and handgrip (HanGrip).

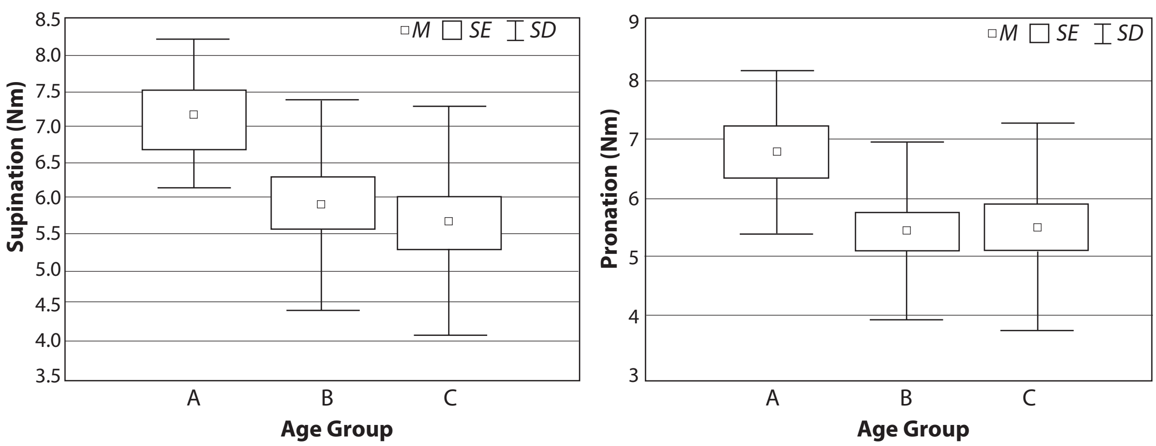

Figure 6. Maximum torques during supination and pronation.

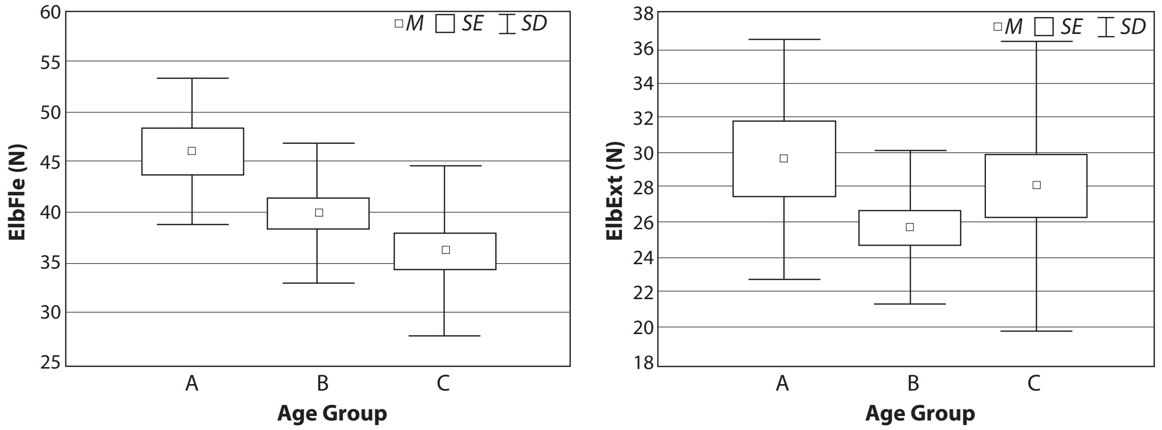

Figure 7. Maximum forces during elbow flexion (ElbFle) and elbow extension (ElbExt).

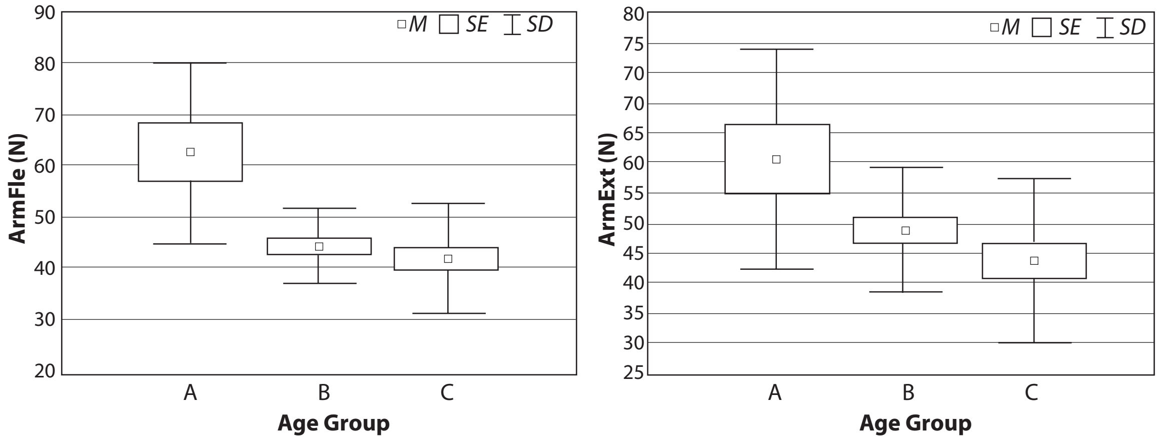

Figure 8. Maximum forces during arm flexion (ArmFle) and arm extension (ArmExt).

obtained in measurements were 25.8–29.7 Nm (Figure 7). There were statistically significant differences for elbow flexion forces. The differences between the 20–25- and the 45–50-year-olds were significant at $p = .042$, whereas those between the 20–25- and the 55–64-year-olds were significant at $p = .001$. The mean values for elbow flexion ranged from 36.4 N for the 55–64 group to 46.2 N for the 20–25 group.

For arm flexion and arm extension the values of force showed statistically significant differences between the 20–25-year-olds and the other two groups (Figure 8). For arm flexion the differences were statistically significant at $p < .001$ for both age groups. For arm extension the differences between the groups of 20–25- and 45–50-year-olds were statistically significant at $p = .027$, whereas between the groups of 20–25- and 55–65-year-olds at $p = .002$.

Table 2 shows percentages of forces obtained for the 45–50- and 55–65-year-olds in relation to the 20–25-year-olds. The obtained values differed

TABLE 2. Decrease in Force Capabilities in Age Groups B (45–50 years) and C (55–64 years) in Reference to the Group of 20–25-Year-Olds (%)

Age Group	HanGrip	LatPinch	Pro	Sup	ElbFle	ElbExt	ArmFle	ArmExt
B	5.44	2.95	19.14	17.73	13.21	13.13	28.82	18.59
C	19.24	9.69	18.16	20.72	21.24	5.18	32.81	26.54

Notes. HanGrip—hand grip force, LatPinch—lateral pinch force, Pro—force of pronation of forearm, Sup—force of supination of forearm, ElbFle—force of elbow flexors, ElbExt—force of elbow extensors, ArmFle—force of arm flexors, ArmExt—force of arm extensors.

among the types of force activities. Lateral pinch decreased by only ~3% in the group aged 45–50 years and 10% in the group aged 55–65, whereas arm flexion force decreased by ~30% in both of those groups.

The correlation analysis conducted to determine the influence of age on force values also showed differences across force types. There was no correlation between age and the values of force for the elbow extension force or for the lateral pinch force. For pronation the significance was at the level of $p = .042$.

Correlation coefficients from .05 to .58 with a negative sign proved that older persons had lower force capabilities (Table 3). Handgrip force had the highest correlation coefficient, followed by supination. This means that age plays a meaningful role in the bigger muscles of the forearm. There was also relatively high correlation of elbow flexion and arm flexion with age. No statistically significant correlation for lateral pinch means that small muscles are less influenced by the ageing process.

TABLE 3. Spearman Correlation Coefficient (*R*) Between 6 Types of Maximum Forces and Age (*N* = 52)

Parameter	*R*	*p*
HanGrip	–.58	.001
LatPinch	–.24	.087
Pro	–.25	.070
Sup	–.38	.005
ElbFle	–.32	.021
ElExt	–.05	.718
ArmFle	–.32	.023
ArmExt	–.30	.034

Notes. HanGrip—hand grip force, LatPinch—lateral pinch force, Pro—force of pronation of forearm, Sup—force of supination of forearm, ElbFle—force of elbow flexors, ElbExt—force of elbow extensors, ArmFle—force of arm flexors, ArmExt—force of arm extensors.

Since handgrip force is very often used as a measure of general force capabilities for the upper limb, it is worth exploring how well handgrip force correlates with other types of upper limb forces. Table 4 presents correlation coefficients with probability levels for the relation between handgrip force and other types of force.

TABLE 4. Spearman Correlation Coefficient (*R*) Between Handgrip Force and Other Types of Force (*N* = 52)

Parameter	*R*	*p*
LatPinch	.35	.011
Pro	.48	.001
Sup	.39	.004
ElbFle	.35	.012
ElExt	.22	.121
ArmFle	.49	.001
ArmExt	.34	.014

Notes. LatPinch—lateral pinch force, Pro—force of pronation of forearm, Sup—force of supination of forearm, ElbFle—force of elbow flexors, ElbExt—force of elbow extensors, ArmFle—force of arm flexors, ArmExt—force of arm extensors.

There were statistically significant correlations with handgrip force in most cases, except for elbow extension forces. This proves that although handgrip force is in step with other types of force there are limitations in treating handgrip as an indicator of general force capabilities.

4. DISCUSSION

The aim of the study was to assess strength capabilities for six types of force, in three groups of women divided according to age. The study also aimed to determine if handgrip force reflected general upper limb force capabilities in relation to the age factor.

Since most studies focus on measurements of handgrip force, this type of force and five others were examined. A comparative analysis of the results done with ANOVA in three age groups (20–24, 45–50 and 55–65 years old) showed a decrease in muscle force related to age. The results showed a reduction in muscle force in most types of force. There were also differences in correlation of force decreasing with age. A decrease in muscle force was mostly related to groups of large muscles of the upper arm girdle (the flexors and extensors of the elbow and shoulder) and was as high as 23%. In the forearm and hand muscles the decrease was lower and did not exceed 10% in the 55–64-year-olds. The loss in force capabilities differed between the types of muscle force, which indicates that loss of force capabilities with age depends on the type of force.

In this study the differences in muscle strength between the age groups were noticeable for all types of force. The highest statistically significant correlation was recorded between handgrip force and age, whereas the lowest between lateral pinch and age.

Handgrip force is commonly accepted as an indicator of force capabilities [29]. In the present study handgrip force for the reference group (aged 20–25) was 415 N. This value can be compared with the values in Su, Lin, Chien, et al.'s [28], Mathiowetz, Kashman, Volland, et al.'s [29] and Mathiowetz, Rennells and Donahoe's [30] studies.

TABLE 5. Age and Mean Values of Handgrip Force in Various Studies (by Age)

Study	Age (years)	Handgrip Force (N)
Mathiowetz, Kashman, Volland, et al. [29]	20–24	313.3
	25–29	331.5
	30–34	350.2
	35–39	329.7
	40–44	313.3
	45–49	276.8
	50–54	292.8
	55–59	255.0
	60–64	245.2
	65–69	220.7
	70–74	220.7
	≥75	189.6
Su, Lin, Chien, et al. [28]	20–29	273.9
	30–39	274.5
	40–49	298.4
	50–59	251.4
	60–69	228.9
Forrest, Zmuda and Cauley [22]	65–69	216.8
	70–74	204.0
	75–79	194.2
	≥80	175.6
Bassey [18]	65	212.0
Present study	20–25	415.0
	45–50	393.0
	55–64	335.5

Various age groups were studied in the past. The present study compares well with Mathiowetz et al.'s [29] study, which considered three age groups: 20–24, 45–49, 55–59 and 60–64 years. Although the groups examined in the present and in Mathiowetz et al.'s study were similar in age, the results differed. Handgrip force measured in the present study was higher by ~30–50%.

When groups similar in age were compared, the results from the present study were higher by ~30–50% than Su et al.'s [28] (groups aged 20–29, 50–59 and 60–69 years), Forrest, Zmuda and Cauley's [22] (a group aged 65–69 years) and Bassey's [18] (a group of 65-year-olds).

This proves that even in similar age groups the absolute value of force can differ greatly depending on the individual characteristics of the studied population, their life activities, the measurement devices used, the experimental setup and upper limb posture (Table 5).

Correlation between handgrip and other types of force was also analysed. The highest correlation was between handgrip, and pronation and supination of the forearm. These parameters are related to each other because the same muscles are used in tests of maximum force. The decrease in these types of force was also similarly related to age, especially in the 55–65-year-olds.

There was a statistically significant relationship between handgrip force, and flexors and extensors of the elbow and arm (shoulder) flexors. However, there was no correlation between handgrip force and the force of arm (shoulder) extensors. Despite the statistically significant correlation between handgrip force, and elbow flexors and extensors, the correlation coefficient was under .35, which explains only ~10% of the correlation between those parameters. A clinical study confirmed there was no correlation between handgrip force and the force of arm extensors [31]. This means that when studying tasks that require the use of muscle flexors and extensors of the elbow, it is not sufficient to determine force capabilities on the basis of handgrip force.

An analysis of the results showed differences in force capabilities related to age and to the type of force activities. This study revealed a different influence of age on muscle force. This means that the age-related muscle force decrease is not linear and is higher in the over-45-year-olds. Those workers are less able to work with greater force. The decrease in muscle force mostly concerns groups of larger muscles (flexors and extensors of the elbow and the shoulder).

The limitation of the study is that only three groups of women in three age groups, under 65 years old, participated in it. The study did not consider physical activity or training, even though those parameters can influence force capabilities. The recorded decrease in muscle force of the flexors and extensors of the elbow and the shoulder predisposes persons over 45 to perform tasks with less load on the whole body and a load similar to that suitable for a young person on the hands or forearms.

Physical exercise can increase muscle force especially if the tested person has not exercised before. The increase in muscle force after a period of training is higher in older people (20%) [32] than in younger ones (7%) [33]. Stabilization of the load of the musculoskeletal system, like sports training in the long term (weight lifting) does not increase force capabilities. Sometimes increasing load in recreationally exercising subjects did not increase their force or power capabilities [34]. However, trained workers can do their job with less load in relation to their force capabilities. Only persons with low physical activity during leisure time took part in this experiment.

5. CONCLUSION

This study proved that workplaces for persons over 45 years old should not require developing great force in the upper extremity girdle, which is present in manual handling, pushing and pulling large and heavy objects. Forces exerted at the workplace by older workers should be ~20% lower than those exerted by workers aged 20–24. However, if the tasks engage small muscles of the forearms and hands, as in assembly or manipulation work, older workers have similar force capabilities as young workers, which means that persons over 45 can perform them.

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