Original paper

Assessment of selected variables of functional capacity in three-generational family households

Ocena wybranych parametrów sprawności funkcjonalnej w rodzinach trzypokoleniowych

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Słowa kluczowe: dwuzadaniowość, sprawność funkcjonalna, prędkość chodu, dziedziczenie genów, proces starzenia.

Abstract

Introduction: Individual functional capacity drops with advancing age, whereas individual gait speed, coded by approx. 69 genes, is one of the widely acknowledged markers of regular fitness.
Aim of the research: The study aimed to assess selected variables of functional capacity in multi-generational families, principally balance and gait speed, whilst probing the intergenerational ties relative to the progression of the aging process, as expressed through the differences in gait speed between the 1st and the 3rd generation.
Material and methods: The study protocol covered 40 individuals originating from 3 generations within the same family households. Individual gait was assessed through a 5-metre gait speed test, along with other tests aimed at assessing individual balance and complex information processing capacity.
Results: A strong, negative correlation was encountered in the gait speed scores between the 1st and the 2nd generation of the same family (respectively, r = –0.81 and p = 0.014). This discrepancy proved the highest between the 1st and the 3rd generation. It also correlated significantly and positively with the actual scope of dual-task motor-cognitive activities.
Conclusions: Progression of the ageing process, expressed as individual gait speed score, was strongly, negatively correlated between respective generations within the same family. The motor variable value rising in the 1st generation translated into an increase in the difference between gait speed in the 1st and the 3rd generation. Gait speed between the 1st and the 3rd generation was dependent on the actual scope of dual-task activities assigned to its respective members.

Streszczenie

Wprowadzenie: Indywidualna sprawność funkcjonalna zmniejsza się z wiekiem, natomiast indywidualna szybkość chodu, kodowana przez około 69 genów, jest jednym z powszechnie uznawanych markerów regularnej sprawności funkcjonalnej w każdym wieku.
Cel pracy: Ocena wybranych zmiennych sprawności funkcjonalnych w rodzinach wielopokoleniowych, głównie równowagi i szybkości chodu, przy jednoczesnym zbadaniu powiązań międzypokoleniowych w odniesieniu do postępu procesu starzenia, wyrażonego przez różnice w szybkości chodu pomiędzy 1. a 3. pokoleniem.
Materiał i metody: Protokół badawczy obejmował 40 osób pochodzących z trzech pokoleń (dziadkowie, rodzice, wnuki lub dzieci) z tych samych rodzin. Indywidualny chód oceniano za pomocą 5-metrowego testu prędkości chodu oraz innych testów mających na celu ocenę także indywidualnej równowagi i zdolności przetwarzania informacji złożonych, czyli wybranych parametrów sprawności funkcjonalnej.
Wyniki: Stwierdzono silną, ujemną korelację w wynikach prędkości chodu pomiędzy 1. a 2. pokoleniem tej samej rodziny (r = –0,81, p = 0,014). Rozbieżność ta okazała się największa między 1. a 3. pokoleniem. Korelowała ona również istotnie i dodatnio z rzeczywistym zakresem dwuzadaniowej aktywności motoryczno-poznawczej.
Wnioski: Progresja procesu starzenia, wyrażona indywidualnym wynikiem prędkości chodu, była silnie, ujemnie skorelowana pomiędzy poszczególnymi pokoleniami w obrębie tej samej rodziny. Wzrost wartości zmiennej motorycznej w 1. pokoleniu przekładał się na wzrost różnicy między prędkością chodu w 1. i 3. pokoleniu. Prędkość chodu pomiędzy 1. a 3. pokoleniem zależała od rzeczywistego zakresu czynności dwuzadaniowych przypisanych poszczególnym jej członkom.

Introduction

Generally acknowledged advances in medical science, in conjunction with the much-enhanced public awareness of appreciable benefits offered by a healthy lifestyle, have been instrumental in the continually swelling numbers of persons over 65 years of age, consequently impacting the Aging Index [1]. The Aging Index, an indicator of a generational relationship between grandparents and their grandchildren [2], is construed as the number of persons aged ≥ 65 years per 100 persons < 14 years of age. As of 1990, seniors have accounted for 10% of Poland's population. This in turn is going to be reflected through the increasingly long intergenerational relationships between grandparents and their grandchildren. Obviously, being confronted with the seniors' appreciably extended lifespan calls for specific measures to be adopted, aimed specifically at promoting successful ageing, to have this issue addressed effectively [2].

The aging process causes a decrease in individual functional capacity. One of the key determinants of individual fitness is one's regular gait. Gait is perceived as a comprehensively structured skill because its overall efficacy is directly dependent upon effective orchestration of many different systems within one's body. A disorder or damage sustained by a single one of them is bound to adversely affect this fitness variable, as well as deteriorate even further, as a particular dysfunction remains unaddressed [2, 3]. The key variables of gait, i.e. speed, length, and width of the stride, and cadence prove most helpful in assessing individual functional capacity [3–5].

It should also be noted at this juncture that gait is by no means a totally automatic activity. This assertion is corroborated through the execution of pertinent dual-task tests [6], subject to manifest control by one's cognitive abilities [6]. Cognitive processes are responsible for the exchange and flow of vital data between an individual and an immediate environment by way of receiving, storing, and processing information, to be subsequently transformed into an adequate bodily response [7–9]. Consequently, the cognitive component controlling any dual-task gait effectively stands for its correct execution. Gait affects the correlations between the key performance variables of all generations within a single family [10]. The outcomes of the studies pursued on twin siblings indicate that genetic factors account for 15–51% of the variance in individual gait speed [11].

The genes affect individual physical activity, both directly and indirectly, by controlling one's energy expenditure [12]. In terms of applicable scientific constraints, 2 major lines of regulation involving genes are distinguished. The first one refers to the protein encoding genes that directly regulate one's energy expenditure, e.g. proteins from the UCP group (uncoupling proteins). Proteins in this group dissipate energy released during respiratory substrates in the mitochondria, as opposed to the ones concentrating energy like ATP synthesis [13]. Polymorphic versions in the coding region of these proteins are characterised by lower activity and thus higher energy expenditure and higher levels of daily physical activity [12].

The other group is made up of the metabolic proteins linked to endocrine functions. The mechanism of hormonal control exerted over one's physical activity may involve a correlation of physical activity with the level of a specific hormone, or an impaired activity of its receptor. This may cause an appreciable drop in the normal concentration of the hormone in the blood stream [13].

Individual muscle strength is part of one's hereditary characteristics [9]. Individual muscle strength is accounted for by the actual location of the genes in one of 16 human genomes. Different genes are responsible for a different type of strength in different muscles [14, 15]. The genes responsible for the hand grip strength are TRIM63 and FBXO63 [10, 14, 15]. One's isometric strength is inherited to a greater extent than muscular endurance [16].

Apart from the genetic aspects, functional fitness may be determined through the assessment of dual-task activities. Available studies indicate that dual-task motor and motor-cognitive activities contribute to enhancement of standing postural control in older adults, as well as boosting their cognitive functions whilst also remaining predictive of the ageing process at large [17].

The study aimed to examine the way in which individual functional fitness was shaped in the multi-generational families, primarily in terms of individual balance and gait.

Study aims and research questions

The study aimed to assess the selected variables of functional capacity in multi-generational families, principally balance and gait speed, whilst probing the intergenerational ties relative to the progression of the aging process, as expressed through the differences in gait speed between the 1st and the 3rd generation.

The following research questions were therefore posed:

1. Do the subjects differ in functional performance, as expressed through individual gait, dual-task motor and motor-cognitive activities, balance, gait speed, and the speed of processing complex information?
2. Does the progression of the ageing process, as expressed in gait speed, indicate a correlation between respective generations within the same family?
3. How significantly is the motor variable in the first generation related to the difference in gait speed between the first and third generations?

The following research hypotheses were posed:

Table 1. Characteristics of the study subjects (*n* =24)

No of subjects	Gender (%)		Age [years] Mean ± SD	Body weight [kg] Mean ± SD	Height [m] Mean ± SD	BMI [kg/m²] Mean ± SD
	Women	Men				
Generation I (*n* = 8)	6.75	2.25	69 ±3.3	76 ±13.3	1.65 ±0.07	28.2 ±4.21
Generation II (*n* = 8)	6.75	2.25	45.9 ±3.5	73.3 ±8.24	1.71 ±0.07	25.21 ±2.5
Generation III (*n* = 8)	6.75	2.25	24 ±2.6	65.9 ±13.2	1.72 ±0.1	22.1 ±2.0

SD – standard deviation, BMI – body mass index.

1. The subjects (between respective generations) differ in their level of functional fitness, as expressed in gait, dual-task motor and motor-cognitive activities, balance, gait speed, and speed of processing complex information.
2. The speed of the ageing process expressed in gait speed indicates a correlation between respective generations within the same family.
3. A motor variable increasing in the first generation indicates an increase in the difference in gait speed between the first and the third generations.

Material and methods

The study protocol covered 40 individuals from 3 generations within the same family households. Generation I comprised the individuals aged 62–72 years, Generation II – the ones aged 41–50 years, and Generation III – those aged 20–27 years (Table 1).

The inclusion criterion was that all 3 generations should be from within a single family household. The exclusion criteria comprised making regular use of orthopaedic supplies, obesity, and having sustained an incidental fall within the last 12 months.

The study protocol embraced 6 young women and 2 young men, 6 adult women, and 2 adult men, 6 senior women, and 2 senior men. Altogether, 16 individuals were dropped from the study protocol outcomes at the results calculation stage due to their non-participation in the Generation I study within their family households.

Written informed consent to attend the study protocol was obtained from each individual.

The Timed Up and Go (TUG) test – preparation for the test entails setting up a chair and demarcating a distance of 3 m in a straight line from it. The starting and finishing position is the subject's sitting down on the chair. At the investigator's command ("off you go, start"), the subject gets up from the chair, walks the pre-determined distance, turns around by 180° to return to the starting position, which marks the end of the test. The duration of the completed task is timed by a stopwatch. This test is meant to assess individual gait and balance [18].

The Timed Up and Go (TUG_{MAN}) test – an additional manual task is added to the basic version of the TUG test. Apart from the gait, the subject is to focus on holding a cup of water in his/her hand throughout the test. This test is meant to assess individual dual-tasking capacity [19].

The Timed Up and Go Cognitive (TUG_{COG}) test – a modified TUG test in which a mental (cognitive) task is added. The subject, apart from the gait itself, is to focus additionally on, e.g., counting down from 100 in units of 7. This test is meant to assess individual gait under the dual-task conditions [20].

Single Leg Stance Open Eyes (SLSOP) test – the subject tries to stand and maintain balance on one leg for as long as possible, with the eyes open, without making use of any supports. This test takes place on a flat surface, and the investigator makes use of a stopwatch to time the subject's ability to maintain a one-legged stand. This test is meant to assess the static body balance [21].

Single Leg Stance Close Eyes (SLSCL) – the performance of this test is similar to the above-referenced version, the only difference being that the subject makes an attempt at maintaining a one-legged stand with his/her eyes closed for as long as possible [21].

The Trail Making Test part B (TMT-B) test – the subject joins the circles featured on a sheet of paper with the letters and numbers inside. The 13 numbers and 12 letters must be connected alternately in numerical and alphabetical order, respectively. The test is timed with a stopwatch, and the subjects are notified of any errors they may have made and are required to correct them, without stopping the timing. The test is meant to assesses the visuospatial aspects of individual memory, attention span, interhemispheric functions, and processing of complex information [22, 23].

The 5-Metre Gait Speed Test – the subject is to walk a distance of 5 metres in a straight line, along a flat surface, at his/her natural gait speed, which is timed with a stopwatch by the investigator. The test is meant to assess individual speed and quality of gait [24].

Dependent variables: Difference in gait speed between respective generations and performance in performing dual-task activities between respective generations. Independent variables: TUG, TUG_{MAN}, TUG_{COG}, SLSOP, SLSCL, TMT-B, and gait speed.

Statistical analysis

Statistical analysis was carried out with the aid of the Statistica 12 PL software package. The normality of the distribution of the variables under study was assessed by the Shapiro-Wilk test ($n < 100$). Descriptive statistics were completed. Pertinent percentage distributions of specific response data, along with the actual number of respondents, were calculated in terms of the qualitative statistics. As far as the variables of quantitative nature were concerned, the mean values or medians and the standard deviations were calculated. Statistical hypotheses were tested for quantitative data with the aid of ANOVA analysis of variance.

The correlation between the variables was tested by making use of the correlation of multiple regression model. The α level was set at 0.05.

Results

The Generation I subjects completed the motor TUG (dual-task) test slower by 86%, as compared to the ones from Generation III. The Generation II subjects, on the other hand, were also slower, i.e. by 39%, as compared to the Generation III ones. Their scores were higher than those achieved by Generation II, i.e. by 20%, and the ones achieved by Generation III, i.e. by 65%. The best scores in the standing on one leg with eyes closed tests were claimed by Generation III. They outperformed Generation I by 375%, and Generation II by 96%. Individuals from Generation I also completed the 5-metre gait speed test at 41% lower than the individuals from Generation III, and 18% lower than the individuals from Generation II (Table 2).

Statistical analysis indicated a significant, strong, and negative correlation between the gait speed of Generation I and Generation II ($r = -0.81$, $p = 0.014$). This means that if the TUG score increased in Generation I, it decreased in Generation II (Table 3).

The inter-generation difference in individual gait speed was the highest between Generation I and Generation III. This difference significantly, positively, and very strongly correlated with the scope of dual-task motor-cognitive activities. This test (TUG_{COG}) accounted for the variability of the difference between GS I and GS III in 87.5% ($p < 0.05$) (Table 4).

The graph shows the distribution of the test results within respective family households. Sixteen family households were investigated, 8 of whom furnished complete results across all 3 generations. The results

Table 2. The comparison between respective generations within a single- family household

Variable	Generation I (n = 8)	Generation II (n = 8)	Generation III (n = 8)
TUG [s], SD	13.81 (3.1)	10.06 (1.5)	7.45 (0.8)
TUGMAN, SD	15.3 (3.04)	11.5 9 (1.49)	8.22 (1.3)
TUGCOG [s], SD	19.95 (3.9)	14.86 (2.81)	10.01 (1.6)
SLSOP [s], SD	16.8 (5.8)	23.2 (3.7)	27.73 (3.3)
SLSCL [s], SD	4.1 (2.5)	9.91 (3.05)	19.5 (4.9)
Gait speed at 5 m distance[s], SD	3.34 (0.4)	2.82 (0.25)	2.37 (0.3)
TMT-B [s], SD	77.14 (20.7)	66.33 (22.67)	40.8 (8.8)

$\bar{x}$ – mean, SD – standard deviation, TUG – Timed Up and Go, TUGMAN – Timed Up and Go Manual, TUGCOG – Timed Up and Go Cognitive, SLSOP – Single Leg Stance Open Eyes, SLSCL – Single Leg Stance Closed Eyes.

Table 3. The correlation between respective gait speeds in all generations

	Gait speed Generation I	Gait speed Generation II	Gait speed Generation III
Gait speed Generation I	–	$r = -0.81$ t(N-2) –3.37 $p = 0.014$	$r = -0.39$ t(N-2) –1.03 $p = 0.339$
Gait speed Generation II	$r = -0.81$ t(N-2) –3.37 $p = 0.014$	–	$R = 0.17$ t(N-2) 0.42 $p = 0.685$
Gait speed Generation III	$r = -0.39$ t(N-2) –1.03 $p = 0.339$	$r = 0.17$ t(N-2) 0.42 $p = 0.685$	–

r – correlation coefficient, R – multiple correlation coefficient.

Table 4. The correlation between individual gait speed and TUG_{COG}

	Difference between GS I and GS II	Difference between GS II and GS III	Difference between GS I and GS III
TUGCOG Generation I	$r = 0.73$ t(N-2) 2.62 $p = 0.036$	$r = 0.61$ t(N-2) 1.88 $p = 0.107$	$r = 0.91$ t(N-2) 5.38 $p = 0.001$ $^*R^2 = 87.52$ $p = 0.001$

r – correlation coefficient, R – multiple correlation coefficient.

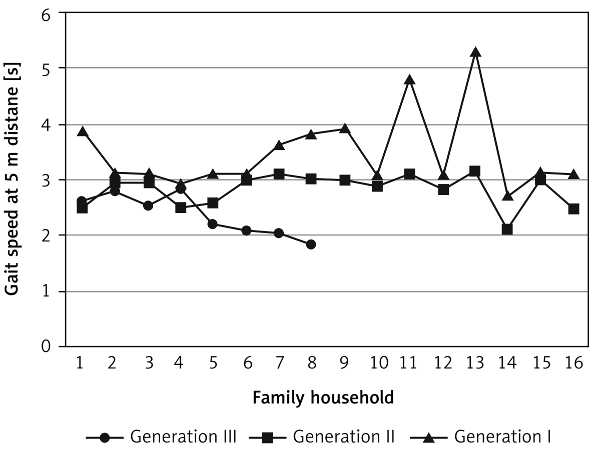

Figure 1. Distribution of respective timings (expressed in seconds) when the members of a single-family household completed the gait speed test over a distance of 5 m

for 2 generations only were collected from 8 family households. As may easily be ascertained from the graph (Figure 1), there is a combination of data between Generation II and Generation III, whereas in the family households where pertinent data were collected from all 3 generations, it would appear that approx. half of the results are indicative of a significant stratification between Generation I and Generation III. It would also appear that gait speed in the youngest generation was the fastest, remaining on the rise in 4 family households, whilst demonstrating no linkage whatsoever with the gait speed of the fathers or grandfathers (Figure 1).

Discussion

The study aimed to probe the nature of the intergenerational relationship, along with the progression of the ageing process. The study attests to a correlation of gait speed between the 1st and the 2nd generation (strong positive correlation, $r = 0.8$). Approximately, 69 genes are most likely responsible for encoding the gait speed [25]. At least 3 of them, PRSS16, WDSUB1, and PTPRT, may be expressed by way of enhancing the synaptic signalling, as well as through an effect of neuroplasticity. In the older adults, these genes were not shown to have been expressed [25].

On the other hand, there is a manifest scarcity of reports on this topic, either originating in epigenetics or genetics focused specifically on investigating the issue of gait speed in seniors. Adams *et al.* demonstrated that heritability was related to individual gait variability (61%), gait rhythm (37%), and the length of the double-pronation phase (32%) because these variables were correlated with body weight and height [26].

Heckerman *et al.* highlighted the ZNF295 and C2CD2 genes, which indicated the inheritance of gait speed (a 4-metre gait test) [27]. Taking due note of these reports, in conjunction with the authors' own study results, being clearly indicative of a high correlation between the 1st and the 2nd generation, may offer further credible evidence of the genetic studies at issue. The strongest correlation was demonstrated not to have occurred between the scope of dual-task activities between the 1st and the 2nd generation, but instead between the differences in individual gait speed values between the 1st and the 3rd generation ($r = 0.9$). In practical terms, this means that high scores achieved within the scope of dual-task motor-cognitive activities would stand to significantly affect this difference.

Consequently, the lower the scores of dual-task activities pursued when young, the smaller would be the difference in gait speed between the youngest and the oldest generation (i.e. 1st and 2nd). None of the studies focused on the dual-task activities, as published to date, have investigated such a linkage, as addressed and diligently probed in the present study.

The outcomes reported by the present study demonstrated the significant differences, as encountered in the test performance time, to be dependent on age. The best results were achieved by the youngest individuals, whereas with each successive generation those values dropped accordingly.

Similar conclusions were reached by Vieira [28], whose study showed a decrease in TUG test scores in each successive age group older by 10 years. The differences in the TUG test scores also varied by gender. Bergland *et al.* [29] reported that men outperformed women on the TUG test within the 65–80 years age range. Their study also looked at the life expectancy in relation to the quality of performance in the TUG test.

All 3 generations scored below normal in the motor-cognitive TUG test. Those from Generation III were the closest to the American norm (9.82 s), whereas those from Generation I completed the test in almost twice the time indicated by the reference values. The best scores in the standing on one leg with the eyes open test were achieved by the Generation III members.

The follow-up regarding the actual rate of individual ageing, spanning almost 12 years, established a strong association between poor TUG test scores and increased mortality in both sexes. De Buyser *et al.* [30] came to similar conclusions during a 15-year follow-up, embracing the subjects with a baseline age of 71–81 years. Also, very poor TUG scores were strongly associated with increased mortality over the following 9 years in the study by Tice *et al.* [31], who investigated subjects with a mean age of 68 years. This test has been proposed as a way of identifying older adults at high risk of adverse health outcomes [32]. The modification of the TUG test by way of adding a cognitive factor is also acknowledged to significantly affect individual gait. The results of the present study indicate that dual-task activity pursued in conjunction with the TUG_{COG} test made the test scores significantly worse across all age groups.

Similar conclusions were reached by Allali *et al.* [33], who introduced a second task apart from gait (i.e. subtracting from a specific number by a fixed amount) during the execution of the TUG test. Dual-task conditions were used specifically to investigate the involvement of the cortical level in individual gait control [34]. Changes in dual-task gait were related to the actual performance of the executive function, the level of difficulty of a specific task assigned to the subject, or the articulo-motor components of a walking-related task [34].

During dual-task gait, a lack of gait deceleration, or even acceleration, may be encountered in some cases. This may be due to the prioritization of gait or cognitive functions during the execution of the test. The focusing of the subject's attention on a motor task (walking) or on a cognitive task (subtracting from a given number by a fixed value) is established to affect the actual outcome of the TUG_{COG} test [35].

The outcomes yielded by the present study highlighted the likelihood of heritability of cognitive prioritisation among the descendants, as a slow-down of individual gait during the execution of the dual-task motor-cognitive test was experienced by all the subjects originating from the same families.

Oh *et al.* [36] conducted a study assessing the static balance of the individuals within the age range spanning 20 years, i.e. up to late adulthood. Their study reported the scores obtained in this test by the individuals aged 20–40 years to be twice as good, as compared to the ones achieved by the subjects over 65 years of age. The authors' own research attested to the scores achieved by the study subjects from the 3rd generation (their grandchildren, great grandchildren) to have been almost twice as good as the ones obtained by the 1st generation (their grandparents).

In view of a small study group, and no opportunity to pursue genetic testing, further studies are planned shortly, with a view gaining as many insights as possible into the issue of heritability of individual gait speed, as well as into key characteristics of the ageing process within members of the same family households.

Conclusions

The respective study groups differed in the score values of the following variables: gait speed, dual-task activities, balance level, and the speed of processing complex information. The 3rd generation of the family boasted the highest scores.

A strong, negative correlation was encountered in the gait speed scores between the 1st and the 2nd generations of the same family. Each successive generation underperformed in gait speed, relative to the previous generation.

An increase in the motor variable value in the 1st generation was also established to translate directly into an increase in the difference between an individual gait speed within the 1st and the 3rd generation. Gait speed differences established between the 1st and the 3rd generation proved directly dependent upon the actual scope of dual-task activities assigned to them.

Conflict of interest

The authors declare no conflict of interest.

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