The assessment of manual dexterity in selected professional groups, using an original program testing the precision of the upper limb and hand-eye coordination

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Abstract

Background: Upper limb motor performance is determined by early and late developmental practice of multifaceted hand movements. Physical activity (PA) also has an impact on physical health, psychosocial, emotional, and cognitive functions. Manual dexterity plays an important role in everyday life and it's a considerable part of one's life is spent at work.

Aims: The aim of the study was to assess manual dexterity in a group of professional IT specialists and handball players using a proprietary programme examining upper limb precision and hand-eye coordination.

Material and methods: A group of 36 people participated in the study (15 handball players and 21 IT specialists). Participants were assessed over two days by a proprietary programme measuring upper limb precision and hand-eye coordination. The programme contained 3 tasks, at 3, 4, and 3 differentiated levels respectively, which were evaluated successively: 1) hand-eye coordination (HEC) and manual dexterity (MD), 2) visuospatial function (VSF) and fine motor skills (FMS), 3) reaction time (RT) and MD.

Results: It was shown that 93% of handball players and 24% of IT specialists had a very high PA index. IT specialists demonstrated better ability compared to handball players, in terms of MD and HEC (p=0.03). Subjects with very high PA index performed worse on the HEC and FMS tasks (p=0.007). Furthermore, with increasing age, MD (p=0.02), VSF (p=0.00024), HEC (p=0.043), and RT (p=0.00044) decreased.

Conclusion: VSF and FMS in IT professionals were better when compared to handball players. Very high PA levels were not associated with improved MD and HEC. Younger individuals showed higher MD, RT, VSF, and HEC scores.

Key words

cognitive functions, manual dexterity, hand-eye coordination, IT specialist, handball player.

Introduction

One of the most important aspects of human motor skills is praxis. It is a motor-cognitive skill that controls the execution of learned, planned movements. Praxis undergoes constant refinement during practical training to the point where it can reach a degree of considerable automation. Performing many motor activities often requires considerable precision, especially hand movements [1].

Upper limb motor performance is determined by early and late developmental practice of multifaceted hand movements as well as the whole limb and physical activity (PA) [2]. Physical activity also has an impact on physical health, psychosocial, emotional, and cognitive functions [3]. The differentiation of motor skills, which begins in adolescence, based on gender, lifestyle, and occupation is most evident in adulthood [4]. Adolescence, in particular the time between 20 and 30 years of age, is potentially a period of peak mobility [5]. Genetics, physical health, and socio-demographic factors, as well as lifestyle, significantly determine the aging process of cognitive functions, including upper limb motor functions [4].

Manual dexterity (MD) plays an important role in everyday life. A considerable part of one's life is spent at work. Research in the field of psychology and workplace ergonomics has proven that jobs that do not require an employee to engage in cognitive functions result in some form of cognitive decline [6]. Additionally, it has been reported that office workers are often characterised by slower cognitive decline when compared to manual workers [7]. It is therefore important to highlight the impact of the occupation on the MD.

Aims

The factors influencing praxis in adults are still not well understood and reports mainly focus on motor development in children. Therefore, the aim of our study was to evaluate praxis in a group of IT specialists and handball players using a proprietary programme to assess MD and hand-eye coordination (HEC), taking into account: age and PA index in the aforementioned groups.

Material and methods

Participants

Thirty-six individuals took part in the study, comprising of 15 handball players (group I) and 21 IT specialists (group II). The group of handball players was exclusively male, while the group of IT specialists included 17 men and 4 women (**Table 1**). The subjects were athletes from Pogoń Szczecin team playing in men's handball super-league, students at the West Pomeranian University of Technology in Szczecin from the Department of Computer Science and IT specialists from private workplaces.

Table 1. General characteristics of the groups.

Characteristics		Handball players (n=15)	IT specialists (n=21)
Sex	Females	0 (0%)	4 (19%)
	Males	15 (100%)	17 (81%)
Handiness	Right-handedness	11 (73%)	20 (95%)
	Left-handedness	4 (27%)	1 (5%)
Physical activity	Very high: >1 training per day	14 (93%)	5 (24%)
	Average: 1-5 trainings per month	1 (7%)	16 (76%)

Inclusion criteria for the study were: occupation as an IT specialist or professional handball player, and age between 18 and 35 years. However, the exclusion criteria were: having an occupation other than IT or being a handball player, age over 35 years, ongoing hand injury or inflammation in the hand area, and lack of consent to participate in the study.

Methods and research tools

Evaluation of MD, including precision of hand movements and HEC, among the occupational groups was done through a proprietary diagnostic programme. It was created on a virtual web platform accessible only on devices such as a computer, laptop, etc. The access was not possible via mobile devices on the grounds that this would have disrupted the process of properly attempting the research, which required the use of a large enough screen and a computer mouse. The programme was powered by the Unity engine and written in the multi-paradigm programming language – C Sharp. Data from the study was stored in a Firebase database. The requirement was to use the equipment, which can be controlled with a computer mouse. The participant (hereinafter referred to as the player) received a link directing them to the programme. By following the link, a registration and login process had to be completed, after which the questionnaire was displayed. Three original tasks at different levels of difficulty were then to be completed:

a) **Rotation of 2D figures** (Task 1, **Figure 1**) – the monitor showed two figures, one of which was rotated by a certain number of degrees in relation to the other. The player's task was to rotate the figure in the shortest possible time, without lifting the mouse, so that it had the same position as the sample figure. Lifting the mouse was an error and resulted in a restart of the attempt. The original task evaluated the HEC and the MD, using an assessment of:

- the total figure rotation (in degrees) performed by the subject during the attempt in each stage of the proprietary diagnostic programme.
- final rotation of the figure - deviation (in degrees) of the figure rotated by the participant from its target position. Measured at the moment when the subject let go of the object, accepting its position as desired.
- the number of attempts at each stage of the proprietary diagnostic programme. Counted from the first attempt to the one that was successful.
- attempt time for each stage of the proprietary diagnostic programme. Counted from pressing the left mouse button to releasing it.

Figure 1. One stage of Task 1, a self-designed program at which hand-eye coordination (HEC) and manual dexterity (MD) were assessed.

b) **Rotation of 3D objects** (Task 2, **Figure 2**) – as in the previous task, two objects in different positions were displayed. Using the mouse, the figure had to be placed in the same position as the sample figure. It was impossible to make a mistake in this task. The programme only moved on to the next level when the task was completed correctly. In this original task, visuospatial function (VSF) and fine motor skills (FMS) were assessed. The evaluation included:

- the final rotation of the figure – the deviation (in degrees) of the figure rotated by the subject from its target position. Measured at the moment when the system has approved the position of the object. Acceptance occurred when the sum of the deviations in the three axes, was less than 5° from the target position of the figure.
- attempt time for each stage of the proprietary diagnostic programme. Counted from the start of the attempt until the figure was placed correctly (automatic acceptance by the system).

c) **Following an object with the cursor** (Task 3, **Figure 3**) – the participant had to keep the mouse cursor on an object moving around the screen for 5 seconds in as smooth of a motion as possible. The moving object decreased in size as the trial progressed. A percentage of the time the player kept the cursor on a moving object was measured. Reaction time (RT) and MD were assessed. The percentage of time the subject managed to hold the mouse cursor on a moving object, relative to the entire trial duration, was analysed.

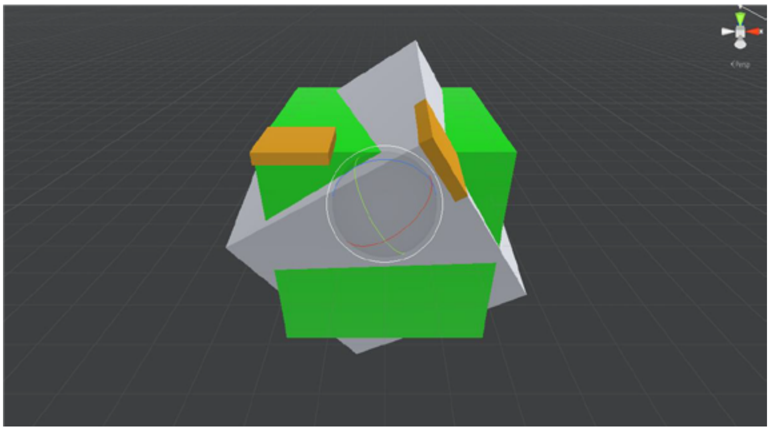

Figure 2. One stage of Task 2, a self-designed program, at which visuospatial functions (VSF) and fine motor skills (FMS) were assessed.

Figure 3. One of the stages of Task 3, a self-developed program at which reaction time (RT) and manual dexterity (MD) were assessed.

Each of the original tasks assessed different aspects of MD. The entire test had to be performed twice, i.e., the same levels were revisited the following day. The data recorded the previous day, allowed the user to log in again as the same subject, making it possible to run the test over the course of two days.

Statistical analysis

The R software was used to carry out the statistical analyses. The Anderson-Darling test was used to calculate the data distribution. The Mann-Whitney-U test for data with a non-parametric distribution and the T-Test for data with a parametric distribution were used to calculate statistical significance. Spearman's Rho was used to calculate correlations. The threshold for statistical significance was $p < 0.05$.

Results

Evaluation of the efficiency and speed of performance on individual tasks assessed using the proprietary programme in group I and group II showed that handball players made more attempts to the HEC and MD tasks when compared to the IT specialists ($p = 0.03$). No statistical significance was obtained in other tasks comparing handball players and IT specialists ($p > 0.05$) – **Table 2.**

Table 2. Analysis of task scores assessing MD, HEC, and RT, in hand players (group I) and IT specialists (group II).

Task	**Group I – hand players** (n=15)				**Group II – IT specialists** (n=21)				P-value
	M ± SD	Me	Min	Max	M ± SD	Me	Min	Max	
Number of at-tempts at the MD and HEC task	9.4±	10	7	13	8.4±	7	3	35	0.03*
Mean time to com-plete the MD and HEC tasks	10.2±	10	10	12	7.4±	5	5	15	0.005*
Mean percentage score in the RT and MD tasks	38.2±	33.2	12.9	102.2	26.3±	20.3	5.9	101	0.05

Abbreviations: *M, mean; SD, standard deviation; Me, median; Min, minimum; Max, maximum; physical activity (PA), manual dexterity (MD), reaction time (RT); p, level of statistical significance.*

There was a significant relationship between average PA level and better HEC and MD ($p = 0.007$) in both groups. However, the group with higher PA index performed the task assessing RT and MD more accurately than the group with average PA, achieving a higher mean percentage score, but no statistical significance was obtained for this parameter ($p = 0.07$, **Table 3**).

Table 3. Analysis of task scores assessing MD, HEC, and RT, in subjects with very high PA (group I) and average PA (group II).

Task	Group with high PA (n=19)				Group with average PA (n=17)				P-value
	M ± SD	Me	Min	Max	M ± SD	Me	Min	Max	
Number of at-tempts at the MD and HEC task	10.7±	10	4	35	6.7±	6	3	14	0.007*
Mean time to com-plete the MD and HEC tasks	2.3±	2.2	1.4	3.5	2.5±	2.3	1.2	5.2	0.49
Mean percentage score in the RT and MD tasks	78±	71.3	52.9	83.9	76.4±	78.4	64.6	94.4	0.07

Abbreviations: *M, mean; SD, standard deviation; Me, median; Min, minimum; Max, maximum; physical activity (PA), manual dexterity (MD), reaction time (RT); p, level of statistical significance.*

We can observe in **Figure 4** the presence of a weak correlation between MD and the age of the subjects. The number of attempts increases with age (p=0.02).

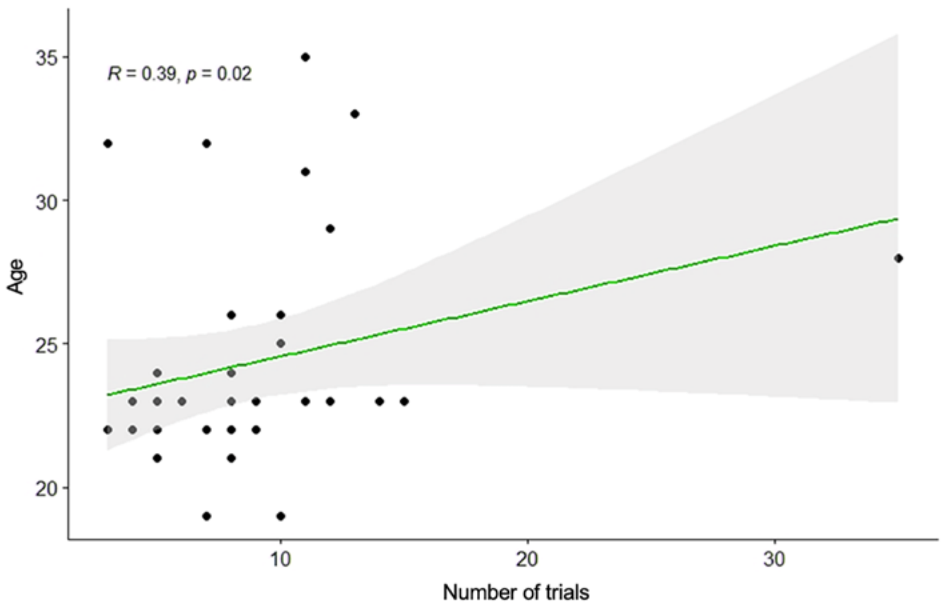

Figure 4. Assessment of the number of task trials testing hand-eye coordination (HEC) and manual dexterity (MD) using a self-designed program among in older and younger adults in groups I and II.

The research found a correlation between age and mean time to complete the task assessing HEC and MD (p=0.043). As age increases, the average time taken by participants to play the game increases (**Figure 5**).

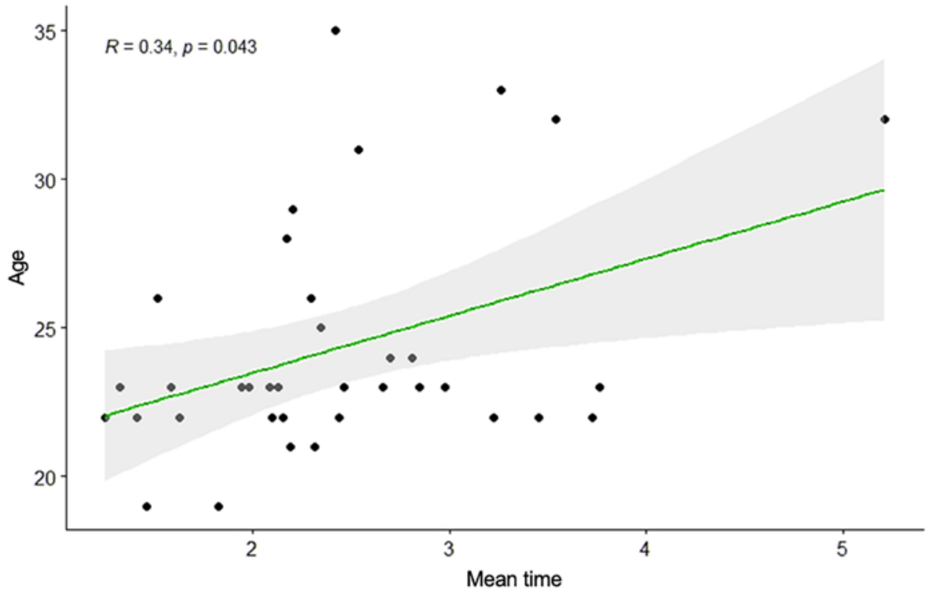

Figure 5. Assessment of mean time to complete a hand-eye coordination (HEC) and manual dexterity (MD) tasks using a self-designed program among older and younger adults in groups I and II.

The analysis revealed a correlation between the age and the mean time to complete the VSF and FMS assessment tasks (p= 0.00024). As age increases, the mean time taken by participants to complete a task increases as well (**Figure 6**).

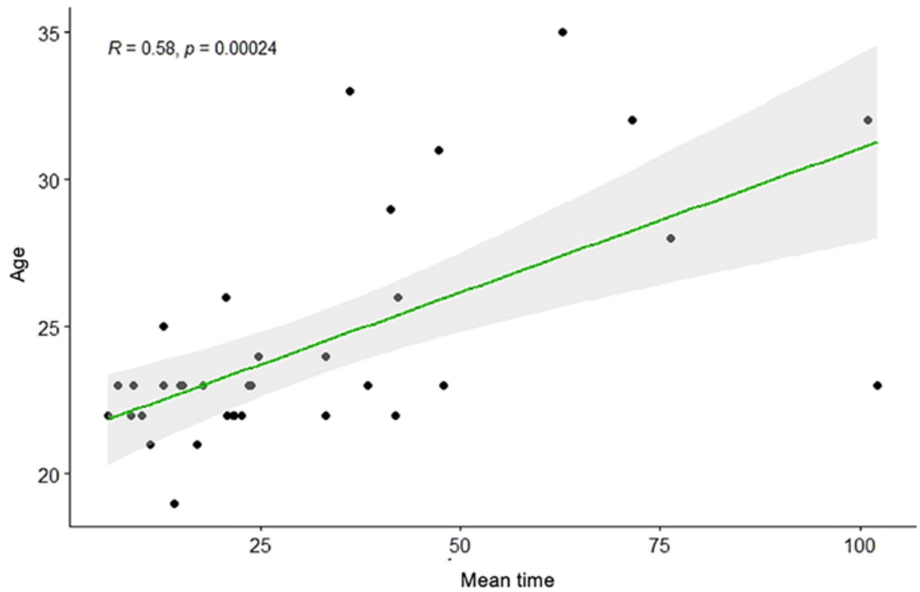

Figure 6. Assessment of the mean time obtained in visuospatial functions (VSF) and fine motor skills (FMS) tasks using a self-designed program among older and younger subjects in groups I and II.

The research indicated that older people scored lower on tasks assessing RT and MD with the proprietary programme when compared to younger people in groups I and II (p=0.00044) (**Figure 7**).

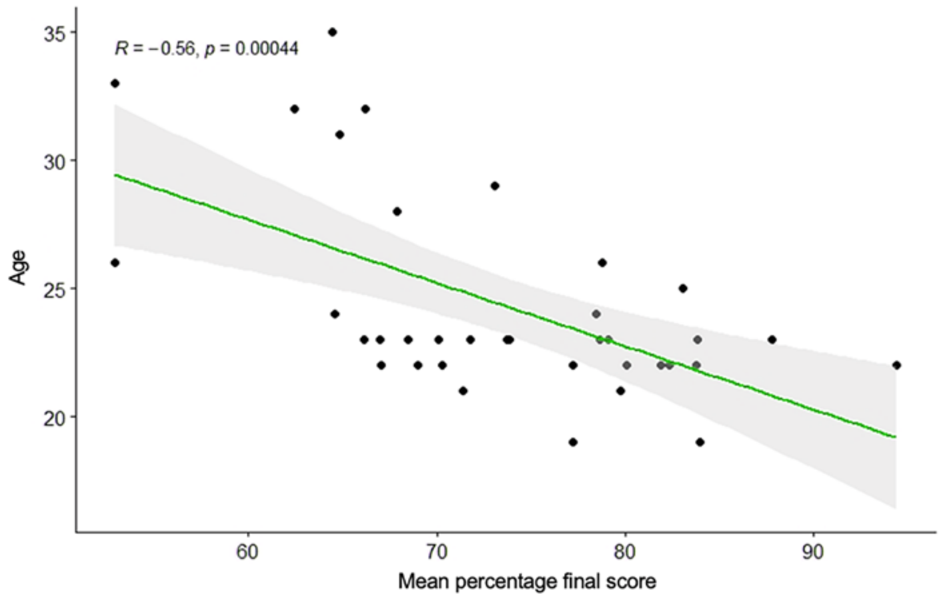

Figure 7. Assessment of the reaction time (RT) and manual dexterity (MD) tasks using a self-designed program among older and younger subjects in groups I and II.

Discussion

This study, using a proprietary diagnostic programme, demonstrated that the number of attempts to complete tasks requiring the use of VSF, MD (mainly FMS), RT and HEC are dependent on occupation (IT specialist or handball player). The obtained results support the hypothesis that undertaking an IT profession has a positive impact on MD, as measured by the proprietary diagnostic programme. Research carried out on professional athletes generally focuses on the assessment of perceptual-cognitive skills, which are related to the ability to identify and gather information to relate it to the knowledge already possessed, in order to select and perform an adequate response to stimuli [8]. Research has shown that elite athletes outperform non-athletes in tasks involving cognitive functions that assess multitasking, working memory, attention, processing and learning speed. They can also better extract relevant information from their environment when compared to non-athletes [8]. The ability to specify information is an important component of motor skills as it determines the quality of the performed movement. Better performance may be due to anatomically increased thickness of the cortex in specific brain areas, which correlates with high levels of physical activity [9]. Professional athletes are usually engaged in enhancing motor skills over a long period of time and can exhibit extraordinary skills in stressful situations. This explains the increase in gray matter density in the left precentral gyrus, known for its substantial contribution to planning and execution of movements, suggesting a specific, action-dependent plasticity of left frontal lobe structures [9].

No research was found to examine the impact of the IT profession on MD or HEC, so to better understand these links, further research is required. In an effort to provide an insight into the impact of the IT profession, an attempt has been made to compare it to that of a professional computer gamer, which is characterised by similar work specificities. There is a possibility that these two professions will similarly affect MD and HEC.

A recent study conducted by Benoit et al. [11] (2020), assessed processing speed (RT), attention, memory, executive functions, and MD among professional gamers, it was found that they had a better developed MD and VSF when compared to amateur gamers [10]. It is considered that computer games can improve brain plasticity and learning. Enhanced learning ability is strongly conditioned by neural mechanisms and computational abilities of the brain. The conditions for experience-based brain stimulation that enhance plasticity in an adult brain are fairly well understood. As are the general response patterns of the neurobiological network of neurons, axons, and dendrites to increased or decreased neuronal activity. Additionally, it has been suggested that computer games improve visual-cognitive functions through enhanced attentional control and executive functioning with an increased ability to select task-relevant information and ignore visual information that is irrelevant [12].

Generally, the IT profession involves the use of sciences (analytical thinking, counting, logic, reasoning, writing), which mainly engage the left hemisphere of the brain. Depending on the IT specialisation pursued, spatial imagination and creativity may also be required, which is primarily the responsibility of the right hemisphere of the brain. In contrast, handball players rely on the use of visual-motor functions, which are not characterised by complete hemispheric dominance. Classical scientific publications on hemispheric specifications – VSF is assigned to the right hemisphere [13]. However, a deeper analysis of more recent publications no longer provides such conclusive evidence [14]. It is difficult to say definitively which exact areas are involved during certain occupations (IT and handball player), therefore further research on this topic is required.

Our research revealed a strong correlation between age and many parameters of each stage of the proprietary MD diagnostic programme. It was observed that in the task examining MD and HEC, younger people performed better. Among the older participants, an increased number of attempts as well as the final rotation of figures is noticeable. Similarly, to the previous results on the VSF and FMS and RT and MD assessment task, younger subjects also performed better. Existing empirical research identifies VSF as an aspect of cognitive functions. The hippocampus, parahippocampal cortex, posterior cingulate cortex, prefrontal cortex, and parietal lobes are thought to have a significant impact on VSF, and are highly susceptible to the effects of ageing, manifesting as a decline in learning ability and executive functioning in older adults. Moreover, maintaining long-term memory and brain plasticity requires gene expression, which is known to decline as the body ages, which may also contribute to the decrease in motor functioning in older people [15]. Interestingly, most biophysical properties of neurons do not change during the ageing process. In the prefrontal cortex and hippocampus, no difference was observed between old and young neurons in their resting membrane potential, threshold for action potential release, build-up time, and action potential duration. However, a significant increase in $Ca2+$ ion conductance is observed in both regions, which is likely to contribute to age-related changes in neuroplasticity. The reduction in neuroplasticity is thought to be responsible for the decline in motor as well as cognitive functioning [16]. New neurons are generated in the dentate gyrus of the adult hippocampus, however, contrary to what was believed in previous years, new neurons are produced even after reaching middle age [17]. Vasylenko et al. [18] (2018) reported that the degree of reduction in hand dexterity among older people, varies according to the type of movement.

With age, precise movements deteriorate more than movements involving larger muscle groups.

Results of our study revealed that the group with very high PA index had, on average, more attempts to complete the HEC and MD assessment tasks than the group with average PA levels. Thus, it can be concluded that more frequent PA does not improve the quality of MD. It is also worth mentioning that in this study, PA index is strongly correlated with occupation, as the results showed handball players have a much higher daily activity rate (93%) than IT specialists (24%). Scientific research investigating the effects of PA index on MD, do not directly relate to the results of our study. Research tends to focus on the claim that PA levels have a positive effect on motor skills, cognitive and executive functions but fails to address the impact of its frequency [19]. PA is thought to maintain physical fitness by delaying the decline in large motor functions. Some studies suggest that the effects of PA on executive functioning are not dependent on the frequency. However, a recent study evaluating the association between PA levels and MD in older adults found that MD is significantly influenced by: PA levels, age, and their interaction effect (PA*age). Furthermore, supplementary comparisons for this study revealed a major effect of PA levels on MD in the older group (>80 years) but not in the younger group [20]. This leads to the conclusion that the results of the above study may be conditioned by the subject's young age, which is not so significantly affected by PA levels. Thus, there is a need for further research in this area. Future studies should consider expanding the research to include an older group of participants to reliably analyse the effect of PA levels on MD.

In addition, other factors determining the quality of cognitive functioning or MD (e.g., sleep deprivation, time of day, diet) may have influenced the outcome. It should be taken into account that the handball players performed their study tasks late in the evening, after a full day's intensive physical activity, which may have reduced the quality of their MD performance. Future research should consider more factors that may determine the quality of MD. In addition, the form of the conducted research is more accessible to IT specialists, as the equipment and platforms used in our study is similar to the ones they work on.

Our study, using a proprietary computer program, is innovative and opens up the possibility of widespread intervention to maintain or improve MD and cognitive functions in people with or without deficits. Through learning about the impact of the occupation on the MD, it is possible to implement the innovations while working, which could include elements that improve performance. This is a remarkably optimistic and at the same time realistic vision, which calls for further research in this field.

Conclusions

The VSF and FMS, which were tested using a proprietary diagnostic programme, are better in IT specialists when compared to handball players. High PA levels are not associated with improved MD and HEC. Younger individuals are characterised by better MD, RT, VSF and HEC scores.

References

1. Domańska Ł, Borkowska AR. (Eds.): Podstawy Neuropsychologii Klinicznej. Lublin: Wydaw. UMSC; 2011. ISBN 978-83-227-2816-1.
2. Zeng N, Ayyub M, Sun H, Wen X, Xiang P, Gao Z. Effects of Physical Activity on Motor Skills and Cognitive Development in Early Childhood: A Systematic Review. Biomed Res Int. 2017 ;2017: 2760716.
3. Haapala EA, Väistö J, Lintu N, Westgate K, Ekelund U, Poikkeus AM. Physical activity and sedentary time in relation to academic achievement in children. J Sci Med Sport. 2017; 20 (6): 583-9.
4. Raczek J. Antropomotoryka. Teoria motoryczności człowieka w zarysie. PZWL, Warszawa 2010.
5. Hallemans A, Verbeque E, Van de Walle P. Motor functions. Neurocognitive Development: Normative Development 2020;157-170.
6. Marquié JC, Duarte LR, Bessières P, Dalm C, Gentil C, Ruidavets JB. Higher mental stimulation at work is associated with improved cognitive functioning in both young and older workers. Ergonomics 2010; 53: 1287-301.
7. Launer LJ. The epidemiologic study of dementia: a life-long quest? Neurobiol Aging. 2005; 26: 335-40.
8. Vaughan RS, Laborde S. Attention, working-memory control, working-memory capacity, and sport performance: the moderating role of athletic expertise. Eur J Sport Sci. 2020: 1-10.
9. Wei G, Zhang Y, Jiang T, Luo J. Increased cortical thickness in sports experts: a comparison of diving players with the controls. PLoS One 2011; 6(2): e17112.
10. Benoit JJ, Roudaia E, Johnson T, Love T, Faubert J. The neuropsychological profile of professional action video game players. PeerJ. 2020; 8: e10211.
11. Bavelier D, Green CS, Pouget A, Schrater P. Brain plasticity through the life span: learning to learn and action video games. Annu Rev Neurosci. 2012; 35: 391-416.
12. Green CS, Bavelier D. Learning, attentional control, and action video games. Curr Biol. 2012; 22 (6): 197-206.
13. Teuber H.L. Why two brains? [In] F. O. Schmitt & F. G. Worden (Eds.), The neurosciences: Third study program. MIT Press 1974: 71-4.
14. Tomasino B, Gremese M. Effects of stimulus type and strategy on mental rotation network: An activation likelihood estimation meta-analysis. Front Human Neurosci. 2016; 693 (9).
15. McAvan AS, Du YK, Oyao A, Doner S, Grilli MD, Ekstrom A. Older Adults Show Reduced Spatial Precision but Preserved Strategy-Use During Spatial Navigation Involving Body-Based Cues. Front Aging Neurosci 2021; 13: 640188.
16. Thibault O, Hadley R, Landfield PW. Elevated postsynaptic [Ca2+]i and L-type calcium channel activity in aged hippocampal neurons: relationship to impaired synaptic plasticity. J Neurosci. 2001; 21 (24): 9744-56.
17. Eriksson PS, Perfilieva E, Björk-Eriksson T, Alborn AM, Nordborg C, Peterson DA, et al. Neurogenesis in the adult human hippocampus. Nat Med. 1998; 4 (11): 1313-7.
18. Vasylenko O, Gorecka MM, Rodríguez-Aranda C: Manual dexterity in young and healthy older adults. 1. Age- and gender-related differences in unimanual and bimanual performance. Dev Psychobiol 2018; 60 (4): 407-427.
19. Hyodo K, Dan I, Kyutoku Y, Suwabe K, Byun K, Ochi G, et al. The association between aerobic fitness and cognitive function in older men mediated by frontal lateralization. Neuroimage 2016; 125: 291-300.
20. Kim N, McGraw R, Thralls K. The Relationship Between Physical Activity Levels and Manual Dexterity in Adults Over 60 Years Old. Innov Aging. 2020; 4 (1): 496-7.