EXPERIMENTAL INVESTIGATIONS

Medicina (Kaunas) 2013;49(1):18-22

Dependence of Reaction Time and Movement Speed on Task Complexity and Age

Tomas Darbutas[1, 2], Vilma Juodžbalienė[1], Albertas Skurvydas[1], Aleksandras Kriščiūnas[3]
[1]Faculty of Sports Biomedicine, Lithuanian Sports University, [2]St. Ignatius of Lojola College,
[3]Department of Rehabilitation, Medical Academy, Lithuanian University of Health Science, Lithuania

Key Words: *reaction time; movement speed; complexity of a task.*

Summary. *The aim of this study was to determine the differences in reaction time, reaction complexity, and movement speed depending on age.*

Material and Methods. The study included 40 healthy subjects (20 young and 20 older women and men). The study was conducted at the Human Motorics Laboratory, Lithuanian Sports University. An analyzer DPA-1 of dynamic upper and lower limb movements was used for the research purposes.

Results. The reaction time of the right arm of the young subjects was 0.26 s (SD, 0.01) and that of the left arm was 0.25 s (SD, 0.02), when an accuracy task was performed. The reaction time of the older subjects was 0.29 s (SD, 0.03) and 0.28 s (SD, 0.03) for the right and left arms, respectively. The reaction time of the right leg of the young subjects was 0.26 s (SD, 0.02) and that of the left leg was 0.27 s (SD, 0.03). The reaction time of the right and left legs of the older subjects was 0.33 s (SD, 0.02) and 0.35 s (SD, 0.04), respectively. The reaction of the young subjects was almost two times faster compared with the older persons after the accuracy task with each limb was accomplished.

Conclusions. In case of movements with arms and legs, reaction time and movement speed directly depend on the complexity of a task. Reaction time and movement speed are slower for the older subjects in comparison with the young ones; the results worsen in proportion to the increasing complexity of a task.

Introduction

Management of human movements is one of the most frequently analyzed areas in contemporary science. Various movement indices, such as reaction time (1–3), mean and maximal movement speed (4), and strength (5–8), are being studied in healthy and unhealthy patients as well as those with movement disorders.

Reaction time is essential when performing a fast movement. It affects the beginning and performance speed of the movement. Reaction time is conditioned by the speed of neural signal transmission to the central nervous system (CNS), decision-making, motor program activation, and signal transmission to muscles (9). In older age, when muscular and nerve tissues weaken, the characteristics of reaction and movement speed change (10–12).

With age, cortical and spinal excitability decreases, characteristics of motor units change, their number and size decrease, muscle mass is reduced, sarcopenia develops, and contractile properties of muscles weaken (13, 14).

A number of studies have analyzed changes in strength at older age, static and dynamic balance, disorders of muscular balance and gait in case of stroke, multiple sclerosis, Parkinson's disease, and endoprosthetic knee and hip joint replacement operations (15–19).

Thus, in the present study, the reaction time and movement speed were investigated in healthy young and older subjects in order to determine the impact of different complexity of tasks and age on movement indices.

Material and Methods

The study included 40 healthy patients (20 young and 20 older women and men) with no movement or CNS disorders. Some previous diseases mentioned in subject's medical documents (coronary heart disease, hypertension, varicose veins, or gastric and duodenal diseases) had no influence on the movement speed and reaction time.

The mean age of the older patients was 62.9 years (SD, 3.5), and the one of the young patients 21.2 years (SD, 2); height was 1.66 cm (SD, 0.06) and 1.75 cm (SD, 0.08); weight, 74.9 kg (SD, 9) and 71.3 kg (SD, 6.4); and body mass index (BMI), 27.2 kg/m^2 (SD, 2.7) and 23.2 kg/m^2 (SD, 1.8), respectively. All the subjects recruited into the study were informed about the study course and volunteered to participate in the research. The Lithuanian Bioethics Committee approved the study (No. BE-2-72).

The study was conducted at the Human Motorics Laboratory, Lithuanian Sports University. An

Correspondence to T. Darbutas, Mosėdžio 7–36, 48177 Kaunas, Lithuania. E-mail: darbtoma@yahoo.com

analyzer DPA-1 of dynamic upper and lower limb movements (patent No. 5251, August 25, 2005) was used for the study purposes. The analyzer is used to evaluate the movement accuracy of one upper or lower limb and the movement coordination of two upper and lower limbs (Fig. 1).

The instrument is made of two measuring devices connected with a stationary standard computer with a Windows operating system (or any other compatible environment) possessing a measurement card with the software and a 17-inch screen. The measuring device consists of the following parts: a mechanism for the transformation of the handle movement into a measuring area, which is 6 times smaller; a mechanism measuring the coordinates of the handle movement; a mechanism determining the horizontal component of the module of strength acting into the handle, together with the strength measuring element; an electromagnetic mechanism for the formation of strength of programmable resistance; a strength measuring unit; a unit for management of strength of programmable resistance; and a power supply.

The measuring devices are mounted onto the support panel on the surface of which handle units are sliding. There are power switches with voltage indicators on the front side and links for the supply cable and a remote start button on the backside of the measuring devices.

Investigation Methods of Movements. During the test, the subjects were seated in a special chair at the table with the DPA-1 mounted. The person's back was straight and leant at the backrest; both arms were bent 90° at the elbow joint so that the upper arms were sided and the forearms rested on the DPA-1 support panel. The position of the DPA-1 chair was regulated so that the subjects could sit comfortably taking a standard position. The distance between the computer screen and the subject's eyes was approximately 0.7 m. During the test of lower limb movements, the chair was placed above the table, and special shoes were put on. The legs were bent 90° at the knee joint.

The subjects performed the tasks of reaction time, maximal speed, and accuracy, which had been anticipated in advance. During each test, the subjects positioned the handle symbol on the screen onto the start area (a green circle 10 mm in diameter). After a certain period, the program generated a sound signal after which the subjects had to perform the task. Later, the recorded indices were analyzed.

The course of the test measuring reaction time, movement speed, and accuracy was as follows:

The essence of the reaction task (RT) was to react to a sound signal as quickly as possible and to move the handle. After the instructions, the subjects were allowed to perform 5 attempts, which were not recorded. Then, the subjects had to perform the task 20 times in sequence starting with the right arm and then with the left arm. During the test, the reaction time in seconds was recorded for both the right and left arm.

Fig. 1. Analyzer of dynamic parameters DPA-1

After 5 minutes, the subjects had to perform the speed task (ST), i.e., to perform a movement as quickly as possible after a sound signal. After the instructions, the subjects were allowed to perform 5 attempts, which were not recorded. Then, the subjects had to perform the task 20 times in sequence starting with the right arm and then with the left arm. During the test, the maximal speed in millimeters per second (mm/s) was recorded for the right and left arm movements.

After 5 minutes, the subjects had to perform the accuracy task (AT), i.e., to perform a movement as quickly and accurately as possible by getting at the target on the screen (a 7-mm red circle) after a sound signal. The distance from the start area to the target was 158 mm. The arm movement pathway was identically repeated on the computer screen. After the instructions, the subjects were allowed to make 5 attempts, which were not recorded. Then, the subjects had to perform the task 20 times in sequence starting with the right arm and then performing it with the left arm. During the test, the reaction time and maximal speed of the right and left arm movements were recorded.

The same tasks were performed with the right and left leg.

Statistical Analysis. Statistical analysis was performed using statistical packages SPSS for Windows and Microsoft Office Excel 2007. The arithmetical means of the indices and standard deviation were calculated; the confidence interval of the difference between the results according to the Student *t* test criterion of independent variables when doing tasks with the right and left arm as well as with the right and left leg and the significance of the results of different variables were determined. The significance level was set at $P<0.05$.

Results

When the RT was performed (Fig. 2), it was determined that the reaction time of the healthy young subjects was 0.22 s (SD, 0.01) for the right and left arm movements. Meanwhile, the reaction time of the older subjects was 0.25 s (SD, 0.03) for the right arm movements and 0.23 s (SD, 0.02) for the left arm movements ($P<0.01$). The analysis of the reaction time with respect to the dominant and nondominant arms used for the movements allowed determining that the reaction time in case of the nondominant arm was similar in both groups of the subjects. The reaction time of the young subjects was 0.24 s (SD, 0.02) for the right leg movement and 0.23 s (SD, 0.01) for the left leg movement; the analogous results were observed in the group of the older subjects, i.e., 0.26 s (SD, 0.01) and 0.25 s (SD, 0.02), respectively.

The analysis of the AT results showed greater differences between the groups of the subjects. The reaction time of the young subjects was 0.26 s (SD, 0.01) for the right arm movement and 0.25 s (SD, 0.02) for the left arm movement; meanwhile, the reaction time of the older subjects was 0.29 s (SD, 0.03) and 0.28 s (SD, 0.03), respectively. Moreover, the reaction time of the young subjects was 0.26 s (SD, 0.02) for the right leg and 0.27 s (SD, 0.03) for the left leg movement, and in case of the older subjects, it was 0.33 s (SD, 0.02) for the right leg and 0.35 s (SD, 0.04) for the left leg ($P<0.05$). Thus, the reaction time of the young subjects was similar to the one of the older subjects for the movements performed with the right arm and both legs. Statistically significant differences were observed between the groups for the movements performed with both arms and both legs ($P<0.01$).

The analysis of the duration of the ST, i.e., the speed of the performed movements (Fig. 3), showed that the fastest movement was performed with the right (dominant) arm in both groups: 1829.59 mm/s (SD, 280.33) in the group of the young subjects and 1558.52 mm/s (SD, 423.05) in the group of the older subjects ($P<0.05$). Besides, the highest speed for the left arm movements was 1628.29 mm/s (SD, 264.32) in the group of the young subjects and 1383.13 mm/s (SD, 317.65) in the group of the older subjects. The highest speed for the dominant (right) leg movements was higher than for the nondominant (left) leg in both groups. The highest speed for the right leg movements was 1682.64 mm/s (SD, 286.76) in the group of the young subjects and 1477.17 mm/s (SD, 388.03) in the group of the older subjects. The speed for the left leg was 1439.5 mm/s (SD, 130.51) and 1293.92 mm/s (SD, 305.91), respectively.

The analysis of the highest speed during the AT showed that the young subjects were twice as fast when performing the movements with each limb separately as the older subjects. The highest speed of the young subjects was 679.37 mm/s (SD, 48.47) for the right arm, 665.78 mm/s (SD, 147.34) for the left arm, 670.53 mm/s (SD, 101.35) for the right leg, and 618.41 mm/s (SD, 127.77) for the left leg; in the group of the older subjects, it was 388.15 mm/s (SD, 112.8) for the right arm, 376.33 mm/s (SD, 122.67) for the left arm, 384.07 mm/s (SD, 77.34) for the right leg, and 310.82 mm/s (SD, 77.89) for the left leg ($P<0.01$). Statistically significant differences were observed between the groups for the highest speed of the movements performed with both arms and legs ($P<0.001$).

The analysis of the movement speed during the ST and the AT showed that the movement speed changed with respect to the used limb in case of the young subjects. In case of the AT, the movement speed decreased by 63% for the right arm, 60% for the left arm, 60% for the right leg, and 58% for the left leg; meanwhile, in case of the older subjects, it decreased by 75% for the right arm, 73% for the left arm, 74% for the right leg, and 76% for the left leg.

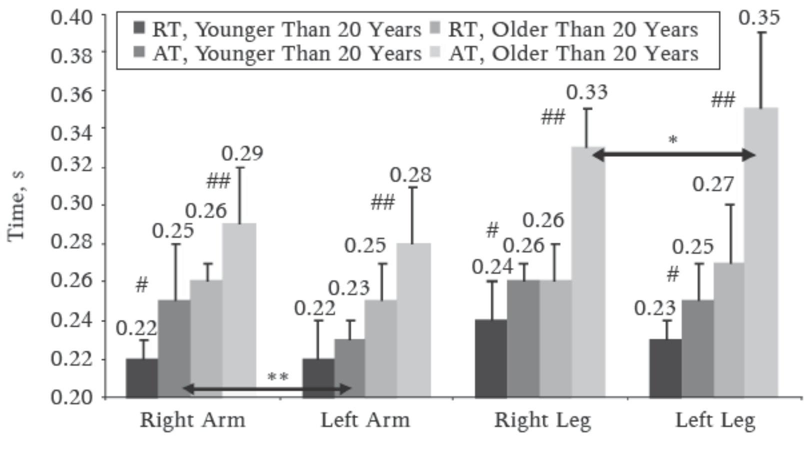

Fig. 2. Reaction time for the movements performed with both arms and both legs
RT, reaction task; AT, accuracy task. *$P<0.05$; **$P<0.01$; #$P<0.05$ (between groups); ##$P<0.01$ (between groups).

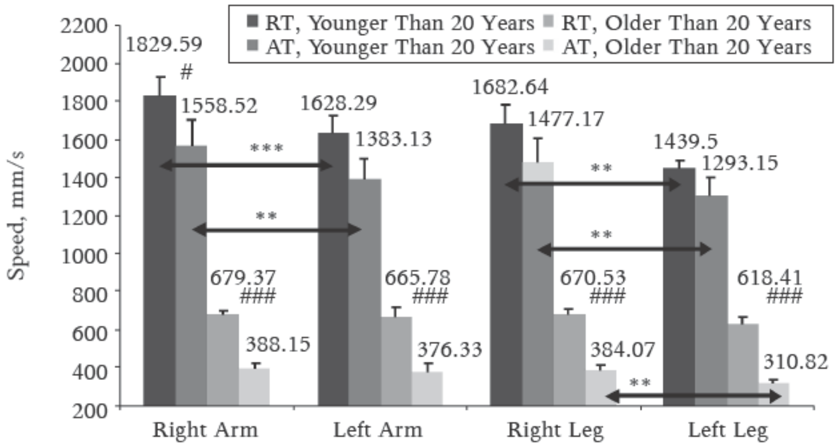

Fig. 3. The highest speed for both arms and legs

AT, accuracy task; ST, speed task.

$^{**}P<0.01$; $^{***}P<0.001$; #$P<0.05$ (between groups); ###$P<0.001$ (between groups).

The results of the study showed a significant correlation between the AT reaction time and movement speed of all the extremities in both groups (Table).

Discussion

The obtained results showed that in both groups, reaction, when performing the tasks of different complexity, was slower when the task was more complicated. Movement planning depends on the complexity of a task, which influences reaction time. This has also been determined by the Hick's law: the more complicated the movement, the longer the reaction time (14, 20).

If the reaction time in case of the RT was evaluated on a 100% scale, the AT results showed that the reaction time of the young subjects increased with respect to the limb used by 8%–18%; meanwhile, the reaction time of the older subjects increased by 16%–40%. Allen et al. found out that subjects of older age needed more time to evaluate the signal and react when performing reaction tasks (2). Our study confirmed that in order to perform a complicated movement, the human brain needs to process more information, which results in longer planning and realization of the movement (21).

In case of the RT performed with arms, a statistically significant difference was observed only in the reaction time between the dominant (right) and nondominant (left) arm of the older subjects. Meanwhile, no significant difference was observed between the right and left arms when performing the accuracy task. According to Zuozienė et al. (2005), some authors have reported the differences in reaction time between the dominant and nondominant arms, while others have not (22).

The analysis of the movement speed showed that the greater complexity of a task resulted in the slower speed of the movement performed with a particular limb. In case of the ST, the differences in the movement speed between the right and left arm and between the right and left leg were significant; meanwhile, in case of the AT, a significant difference was observed only in the movement speed of the right and left leg of the older subjects. A study by Benedetta et al. showed a greater movement speed in young subjects, when movements were performed with an arm in comparison with older subjects, which was also confirmed by the results obtained in our study (23).

If the movement speed in the ST was evaluated on a 100% scale, in case of the AT the speed slowed

Table. Correlation Coefficients Between Reaction Time and Movement Speed in Accuracy Task

			Reaction Time			
			Right Arm	Left Arm	Right Leg	Left Leg
Movement speed	Right arm	Young Older	–0.778* –0.904**	–	–	–
	Left arm	Young Older	–	–0.933** –0.827*	–	–
	Right leg	Young Older	–	–	–0.718* –0.828**	–
	Left leg	Young Older	–	–	–	–0.903* –0.979**

$^{*}P<0.05$; $^{**}P<0.01$.

in both groups by 50%, i.e., by 58%–63% in the group of the young subjects and by 73%–76% in the group of the subjects of older age.

According to Bonnetblanc, the more accurately the movement has to be performed, the slower the speed is (24); this fact was confirmed by the data of our study, too. It is complicated to coordinate movement accuracy and speed since the duration of the movement shortens when it is performed faster, which results in fewer correction possibilities (25).

In order to perform an accurate movement, it is more complicated for the CNS to plan and correct it, which results in more errors; meanwhile, with a slower movement speed, fewer mistakes are done, and the movement is more accurate due to a longer period of time spent on it (14). According to Latash, the more complicated the movement is, the longer it takes for the brain to create a plan and a program for the movement; its realization is longer as well (26).

Conclusions

In case of movements with arms and legs, reaction time and movement speed directly depend on the complexity of a task. Reaction time and movement speed are slower for the older subjects in comparison with the young subjects; the results worsen in proportion to the increasing complexity of a task.

Statement of Conflicts of Interest

The authors state no conflict of interest.

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Received 21 June 2012, accepted 31 January 2013