Keyboards types of selected electronic devices and the occurrence of pain in the shoulder girdle and upper limb – a review of literature

Typy klawiatur wybranych urządzeń elektronicznych, a występowanie dolegliwości bólowych obręczy barkowej i kończyny górnej – przegląd piśmiennictwa

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Key words
Keyboards, ergonomics, pain

Abstract
Introduction: Nowadays, computers, personal telephones (smartphones) and other electronic devices are widely used in many areas of everyday life, making them indispensable tools in the workplace, as well as other environments, e.g. at home. Studies from recent years have shown that the mere use of a computer keyboard for many hours carries the risk of pain in the hand, forearm, arm, shoulder girdle, neck and other parts of the motor organs.
Aim: The aim of the literature review carried out in this work was to determine what potential threats are posed by standard keyboards and smartphone touch keypads, as well as the comparison of standard and ergonomic keyboards.
Material and methods: The following databases were searched: PubMed, ResearchGate and Cochrane Library, in which 13 articles meeting the inclusion and exclusion criteria were found (6 regarding standard keyboards, 3 concerning ergonomic keyboards and 4 related to smartphone keypads).
Results: The results of these studies indicate exposure to dysfunctions of the musculoskeletal system associated with typing on keyboards, especially when writing fast, with high pressure, in unnatural positions of the wrists and forearms and during long-term writing. Ergonomic keyboards can be a good alternative to standard keyboards, especially for those who use one for more than four hours a day. This literature review indicates the need for more research, especially randomized clinical trials among a large population.
Conclusions: 1. The use of keyboards of selected electronic devices with different ergonomic characteristics has an adverse effect on the functionality of the shoulder girdle and upper limb, mainly generating painful symptoms with different clinical characteristics. 2. The most important influence on the occurrence of functional disorders and pain complaints concerning the shoulder girdle and upper limb when using a keyboard with different ergonomic characteristics regards the strength of pressure on the keys, speed of typing as well as long-lasting and forced positioning of the wrists and forearms.

Słowa kluczowe
klawiatury, ergonomia, dolegliwości bólowe

Streszczenie
Wstęp: W dzisiejszych czasach komputery, telefony osobiste (smartfony) i inne urządzenia elektroniczne znajdują szerokie zastosowane w wielu dziedzinach życia codziennego, przez co stały się wręcz niezbędnymi narzędziami w wielu miejscach pracy, a także poza nią, np. w domu. Badania ostatnich lat pokazały, że już samo używanie klawiatury komputerowej przez wiele godzin niesie za sobą ryzyko występowania bólów w obrębie ręki, przedramienia, ramienia, obręczy barkowej, szyi jak i w innych częściach narządu ruchu.

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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Cel: Celem dokonanego w tej pracy przeglądu literatury było ustalenie jakie potencjalne zagrożenia stwarzają klawiatury standardowe i dotykowe smartfonów, a także porównanie klawiatur standardowej i ergonomicznej.
Materiał i metody: Przeszukano bazy: PubMed, ResearchGate i Cochrane Library, w których znaleziono 13 artykułów spełniających kryteria włączenia i wyłączenia (6 dotyczących klawiatur standardowych, 3 klawiatur ergonomicznych i 4 klawiatur smartfonów).
Wyniki: Wyniki tych badań wskazują na narażenie na dysfunkcje układu mięśniowo-szkieletowego związane z pisaniem na klawiaturach, zwłaszcza podczas pisania szybkiego, z dużą siłą nacisku, w nienaturalnych pozycjach nadgarstków i przedramion oraz podczas pisania długotrwałego. Klawiatury ergonomiczne mogą być dobrą alternatywą klawiatur standardowych, szczególnie dla osób używających klawiatury ponad cztery godziny dziennie. Niniejszy przegląd literatury wskazuje na potrzebę wykonania większej ilości badań, zwłaszcza randomizowanych badań klinicznych na dużej liczbie populacji.
Wnioski: 1. Korzystanie z klawiatur wybranych urządzeń elektronicznych o zróżnicowanej charakterystyce ergonomicznej, wywiera niekorzystny wpływ na funkcjonalność obręczy barkowej i kończyny górnej generując przede wszystkim ich dolegliwości bólowe o różnej charakterystyce klinicznej. 2. Najistotniejszy wpływ na występowanie zaburzeń funkcjonalnych i dolegliwości bólowych obręczy barkowej i kończyny górnej u korzystających w czasie pisania z klawiatur o zróżnicowanej charakterystyce ergonomicznej, ma siła nacisku na ich klawisze, szybkość pisania oraz długotrwała i wymuszona pozycja nadgarstków i przedramion.

INTRODUCTION

Nowadays computers, smartphones and other electronic devices are widely used in many areas of everyday life, making them indispensable tools in many workplaces, as well as at home. Many of us cannot imagine life and everyday functioning without them. Over the past 50 years, researchers have proved that merely using of a computer keyboard for many hours is associated with hand, forearm, arm, shoulder girdle and cervical spine pains[1-3]. These problems are related to high repeatability of movements, incorrect organization and ergonomics of work, excessive number of hours spent in front of the computer and the unnatural position while using the keyboard consisting of, among others, shoulder elevation, deviation in the radiocarpal joint or rotation of the head[4,5]. Research by Baker et al.[6] showed that about 20% of computer users have experienced various types of musculoskeletal disorders of the upper limbs.

The basis of correct computer use is ergonomic position and working conditions. Workplace ergonomics prevents musculoskeletal disorders: it consists of, i.e., the correct height of the desk and chair, the right angle of the display and its distance from the eyes, as well as the correct keyboard angle and its location in relation to the worker, the presence of a pad with a wrist rest under the so-called control mouse, as well as additional elements such as forearm supports[2,7-10]. Kaliniene[11] carried out research on 513 office employees using a computer in their daily work, in which he confirmed the relationship between the occurrence of musculoskeletal pain of the shoulder, elbow, wrist and back, and the ergonomics at work. Despite this, almost half of the computer users are not aware of the rules of safe ergonomic practice[12].

Keyboards

One of the aspects of the construction of computer keyboards is that the key layout in most of them is not particularly ergonomic. The very often used “backspace” and “enter” keys are located in inconvenient places on the edge of the keyboard, which enforces the use of the smallest and weakest finger. If one types quickly, it can lead to numbness and even pain. In addition, in the situation of intensive use of a standard computer keyboard, the so-called “QWERTY” keyboard (Figure 1), it is difficult to protect against upper limb pain caused by incorrect hand positioning. Forearm pronation, wrist extension and its ulnar deviation are risk factors for musculoskeletal discomfort[2,4].

The most serious pathology to which fast and long-lasting keyboard typing can lead is the carpal tunnel syndrome[13]. It leads to tingling, numbness, pain and hand muscle weakness. The occurrence of this syndrome is most affected by performing repetitive manual activities, incorrect positioning of the wrist, forearm, fingers, as well as the force used when pressing fingers on the keys[14]. In addition, the risk increases with the use of a keyboard for over 20 hours a week. Studies with the use of an ultrasound machine showed that after an hour of continuous typing on the keyboard, edema of the median nerve of both hands occurs[1,15].

Figure 1
Standard keyboard

A simple ergonomic recommendation for computer users is to adjust the keyboard or workplace so as to reduce wrist extension and its ulnar deviation. This can be achieved by changing the keyboard height, using an ergonomic keyboard, placing the keyboard flat, using a negative slope keyboard or using the forearm support. These supports are usually attached to the desk. Some of them have height adjustment, so that their position can be individually adjusted to reduce the wrist extension, as well as reduce the strain on the arm and shoulder muscles[16,17].

Ergonomic keyboards are designed to reduce muscle tension during use and prevent many of the associated problems. Working on them should not burden wrists as much as working on standard keyboards[18]. People accustomed to the standard keyboard are not willing to change it because they think that it will be difficult for them to adapt to the new way of typing, and that writing efficiency will decline[19]. The solution to this problem may be an ergonomic split keyboard (Figure 2), which has a traditional layout but with V-shaped keys. The keys are divided into 2 groups, allowing the user to put the wrists in a more natural position compared to a standard keyboard.

Along with technological progress, devices with touch keyboards started to appear on the market, such as tablets or mobile phones. Nowadays, we often meet people who can not imagine life without a smartphone. Since these technologies have been introduced into workplaces and for everyday use, there has been concern about the health consequences of mainly the musculoskeletal system caused by overuse of these devices. The thumb is mainly exposed, because it is used to type and browse the contents of such a phone, although there are also people who use their index finger for this purpose[20]. People using smartphones mainly assume three different ways of typing: one-handed and two-handed, with the thumb, used by 95% of them; and people using one hand to hold the phone and type with the index finger, representing only 2%[21]. As a consequence, most of the published studies concern the consequences of typing using smartphones with the keyboard and with the help of thumbs. An increasing number of these studies showed inflammatory states of the joints, tendons and tendonous sheaths among people sending a large number of text messages via such a phone[22,23].

STUDY AIM

The aim of the study was to analyse the risks to the shoulder girdle and upper limb resulting from the use of keyboards of selected electronic devices, including computers and personal phones with different ergonomic characteristics, and above all, to answer the following questions:

1. What effect does the use of electronic devices with different ergonomic characteristics have on the musculoskeletal system of the shoulder girdle and upper limb?
2. What and what conditions of using selected electronic devices with different ergonomic characteristics have the most significant impact on the functional risks to the shoulder girdle and upper limb arising in this mechanism?

RESEARCH MATERIAL AND METHOD

The objective of the study was based on analysis of professional scientific reports available in literature.

Search strategy

The search of professional scientific reports regarding subject-related research aims was conducted in the following electronic databases: PubMed, ResearchGate and Cochrane Library. The search lasted from October 2016 to September 2017, wherein combinations of keywords were used: "*keyboard*", "*keyboarding*", "*ergonomic keyboard*", "*split keyboard*", "*alternative keyboard*", "*keyswitch*", "*pain*", "*discomfort*", "*mus-*

Figure 2
Split keyboard

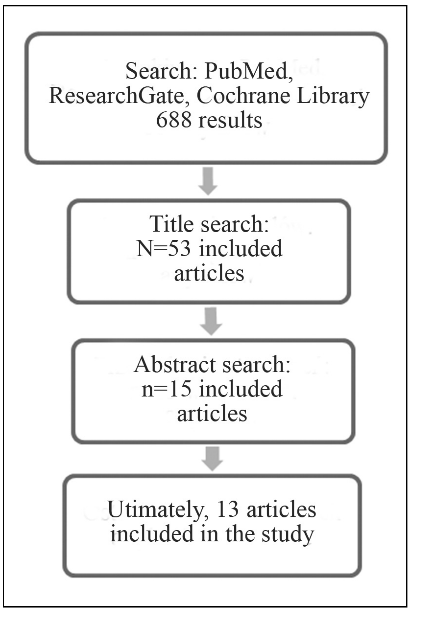

Figure 3
Literature search scheme

culoskeletal", "*upper extremities*", "*upper limbs*", "*carpal tunnel syndrome*", "*median nerve*", "*wrist posture*", "*muscle activity*" and "*smartphone*". All the titles and relevant abstracts were analysed.

The scheme for the search strategy is presented in Figure 3.

Inclusion and exclusion criteria

In order for the article to be considered, it had to meet the following inclusion criteria: the study concerned a standard, ergonomic or smartphone keyboard; the impact of using the keyboard on the upper limb and/or the shoulder girdle; and the language of the articles was English or Polish. Research both on healthy people and people with specific ailments, such as, among others, paresthesia of the hands or carpal tunnel syndrome was considered.

Articles on laptops, notebooks and tablets and keyboards (instruments) were not included. The presented analysis does not comprise reports published before 1999, which limits the range of the analysed reports from 1999 to 2017 (Table 1 and 2).

Table 1

Inclusion and exclusion criteria for the study
Inclusion critieria
Subject of research
Standard keyboard
Ergonomic keyboard
Smartphone touch keypad
Aim
Influence of keyboard on upper limb and/or shoulder girdle
Methodology
Randomized and non-randomized clinical trial
Prospective cohort study
Cross-sectional study
Language
English
Polish
Exclusion criteria
Subject of research
Laptop or notebook keyboard
Table touch keyboard
Keyboard instruments
Methodology
Case study
Year
<1999

RESULTS

The adopted research methodology resulted in 13 scientific reports with the expected thematic characteristics, 6 of which were related to the use of standard keyboards[14,24-27], 3 to the use of computer ergonomic keyboards[28-30] and 4 determining the variables tested in people using personal phones (smartphones)[31-34]. There were no national scientific reports in the collected material (Table 2).

Standard keyboards

The occurrence of pain in the upper limb and neck

The relationship between the occurrence of pain in the upper limb and neck and the use of a standard keyboard was examined, among others, by Palmer et al.[24]. The authors conducted a survey among a group of 1,798 office workers using standard keyboards regularly for at least 4 hours a day. A total of 30% of the respondents reported pain in the neck or upper limb during the week before the examination, and 15% reported tingling or numbness in the upper limb for more than 3 minutes.

Table 2

Thematic description of publications included in the study

Author of publication	Year of publishing	Number included in the study	Research methodology
Toosi[1]	2011	20	PCS
Rempel[14]	2008	20	PCS
Palmer[24]	2001	1798	CSS
Gerard[25]	1999	24	PCS
Rempel[26]	1999	20	RCT
Szeto[27]	2005	41	NRCT
Szeto[28]	2000	10	PCS
Tittiranonda[29]	1999	80	RCT
Marklin[30]	2001	11	PCS
Yang[31]	2017	315	CSS
Lee[32]	2015	10	PCS
Inal[33]	2015	102	PCS
Qasim[34]	2017	357	CSS

PCS – prospective cohort study; RCT – randomized clinical trial; NRCT – non-randomized clinical trial; CSS – cross-sectional study

Pressure and pain in the upper limb and shoulder girdle

Increased muscle activity that lasts for a long time can contribute to their weakness and even pain. Therefore, it is important to use as little pressure as possible when typing for a long time. In order to study the activity of the flexor and extensor muscles of the upper limb fingers while typing on standard keyboards with different key stiffness, Gerard et al.[25] performed electromyographic examinations on people experienced in typing. The test involved the use of keyboards with different keystroke characteristics (i.e. the force needed to activate the key): 0.28N, 0.56N, 0.83N and 0.72N, with the latter being a control keyboard. The control keyboard differed from the others in the construction of the keys, under which there were springs; the remaining keyboards had rubber domes under the keys that gave them a determinable stiffness. The study shows that the force used for writing was significantly greater in the case of the keyboard with the required pressure force of 0.83N than in the case of other keyboards. On the other hand, similar force was used on the 0.28N and the 0.72N spring keyboards. After the period of using each keyboard, the respondents were asked about their subjective feeling of discomfort. The greatest discomfort, both in the fingers and in the forearm, was noted in respondents who used the stiffest keyboard, i.e. the one requiring a pressure force of 0.83N. There were no significant differences in discomfort in the shoulders or the neck. 17 out of 24 respondents also stated that they preferred using the spring keyboard with the required pressure force of 0.72N. The authors of this report suggest that it may indicate a difference in the way of typing on the spring keyboard and the keyboard with rubber domes.

The impact of key stiffness on hand pain was also examined by Rempel et al.[26]. The study included users of standard computer keyboards reporting paresthesia of hands, who the scientists divided into two groups – the test and control group. The control group used a keyboard with rubber domes for 12 weeks, while the study group used a less stiff Protouch keyboard for the same period of time. The keyboards differed in required pressure force and in the resulting technological mobility. These characteristics of the keys in the Protouch-type keyboard, according to the users, gave it a feeling of "lightness" and provided more comfort compared to the keyboards used by those included in the control group. Among the subjects using the Protouch keyboard, the authors reported a reduction in pain in the hands and a negative Phalen test, which took place between the 6th and 12th week of the study. In the control group, however, the authors registered a considerable increase in these ailments.

Szeto et al.[27] examined the impact of the pressure exerted on the keyboard keys and typing speed on the activity of the hand muscles. Using an electromyograph, they examined four muscles on both sides of the body: the cervical spine rectifier, the upper and lower parts of the trapezius muscle and the anterior deltoid muscle. These are the main stabilizing muscles around the neck and shoulder, which may be exposed to biomechanical loads when typing on a keyboard. People in the group claimed that during the last year, at least for three months, as well as on the day of the examination, they felt discomfort associated with using the computer. The participants were asked to type on a standard keyboard three times for 20 minutes: first, they typed at their normal pace and strength, then with 20% more speed, and finally with 20% more strength. The examination showed greater increases in muscle activity during faster typing compared to typing with greater pressure force in both study groups. The study group, however, showed greater activity increases than the control group. In addition, the extensor and the lower part of the trapezius muscle on the right side of the body showed significantly higher activity. In addition to the electromyographic examination carried out every 5 minutes, participants were also asked about their feelings of discomfort. The progressive increase in discomfort in the study group was higher during faster typing compared to typing with stronger pressure on the keys, whereas in the control group the discomfort was similar in both cases.

Effect on the median nerve

Long-lasting pressure on the median nerve in the carpal tunnel resulting from e.g. the increase in pressure in the canal poses a high risk of pain and discomfort. The results of two studies quoted below indicate that there is a relationship between typing on a computer keyboard and the damage of the median nerve.

The first test, by Toosi et al.[1] was performed using ultrasound images taken at the level of the distal radius and the pisiform bone. The participants were people with significant typing skills, who use all the fingers of their hands and write daily for at least 4 hours. After an initial ultrasound examination of the wrists of both hands (dominant and non-dominant), the participants typed on a standard keyboard for 60 minutes; then, another ultrasound examination followed. The results of this study showed an increase in the cross-sectional area of the examined wrists by 7% and an increase in their edema.

On the other hand, Rempel et al.[14] performed a test using a special catheter that measured the pressure inside the wrist channel when typing on a keyboard in different wrist positions: at 15° to 45° extension, flexed at 15°, in the neutral position, and ulnarly and radially deviated. The authors have shown that the pressure inside the carpal tunnel changes with the change of the hand position and that it increases during writing compared to the static position. The highest pressure appeared when writing in the position of a 45° extension and amounted to 4.0 kPa, which means that it was about twice as high as in flexion and the neutral position (1.9 kPa). Significantly higher pressure also occurred when radius-directed compared to the elbow-directed and neutral positions.

The studies described above are shown in Table 3.

Table 3

The influence of using standard keyboards on the occurrence of pain in upper limbs and shoulder girdle

Source	Method of study	Occurrence of pain/discomfort	Cause of pain
Palmer[24]	Questionnaire	Neck and the upper limb	Using a keyboard for ≥ 4 hours a day
Gerard[25]	EMG	Fingers, forearms	Using a keyboard with high key stiffness
Rempel[26]	Questionnaire, Phalen's test	Paraesthesia of the hands	Pain intensification while using a keyboard with high key stiffness
Szeto[27]	EMG	Possible pain of neck/shoulder stabilising muscles	Increased muscle activity during faster typing
Toosi[1]	USG	Possible pain in the wrist area	Increased pressure in the carpal tunnel after 1 hour of typing
Rempel[14]	Catheter measuring the pressure inside the carpal tunnel	Possible pain in the wrist area	Increased pressure in the carpal tunnel in great extension

Ergonomic split keyboards

Szeto et al.[28] compared the muscle activity of the wrist extensors with the wrist position when typing on standard and split keyboards (Figure 4). The tests included only the right upper limb. The subjects typed on both keyboards for 30 minutes, during which every 2 minutes an electromyographic examination was performed on the two main wrist extensors: extensor carpi radialis longus and extensor carpi ulnaris muscles, while the wrist extension and the ulnar deviation (movement) were measured using a standard hand goniometer. The study showed that muscle activity during typing on a split keyboard is smaller compared to a standard keyboard. Also, the angles of the wrist during typing were more advantageous in the case of the split keyboard, as shown in Table 4.

Another comparison of keyboards was conducted by Tittiranonda et al.[29], who combined a standard keyboard with three alternative split keyboards: Apple Adjustable Keyboard™, Comfort Keyboard System™ and Microsoft Natural Keyboard™. The first keyboard had the ability to adjust the angle of the keys for both hands in one plane, so as to reduce the ulnar deviation of the wrist, while the second keyboard could also be set in two steps to reduce the pronation of the forearms. The third keyboard was a regular split keyboard, with no possibility of adjustment. The subjects were diagnosed with carpal tunnel syndrome or inflammation of wrist tendons; the duration of computer use was at least 20 hours per week. Four groups of participants in this study used a given keyboard every day for six months. Half of the control group who typed on a standard keyboard reported no change in the pain intensity after six months, while 25% reported moderate or significant deterioration. In subjects who used alternative keyboards, there was a significant reduction in pain. The largest number of people who reported a significant reduction in pain after six months belonged to the group using an alternative keyboard, which was noted in 55% of them. In the second group, there were 40% of them, and in the first group, 35%.

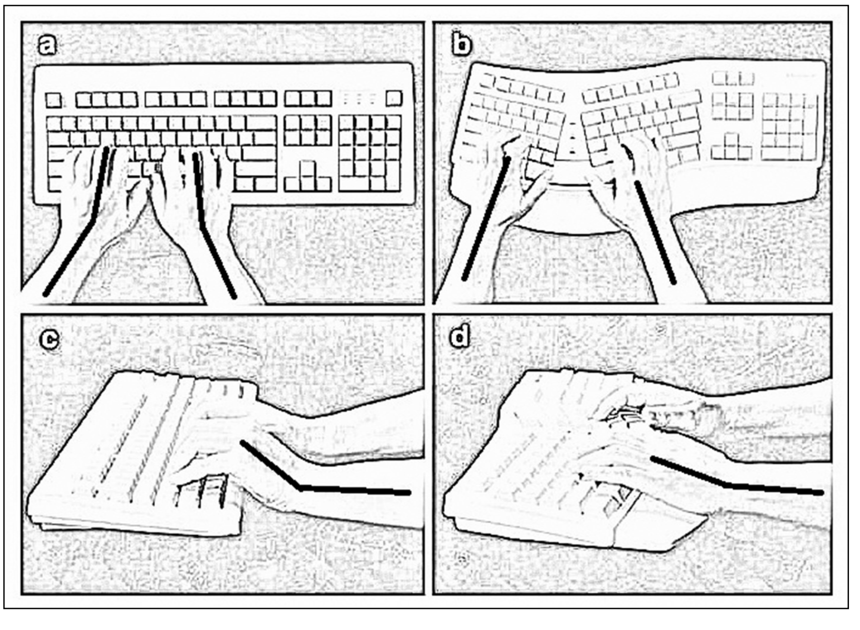

Figure 4

Wrist placement while typing on a standard and ergonomic keyboard[28]

Marklin et al.[30] examined the effects of various split keyboard settings on deviations of the wrists compared to the standard setting[30]. A split keyboard was used for this purpose, with the option of dividing it in two parts and setting at various angles which, during the test, were adjusted to the theoretically neutral position of the users' wrists (in addition to the standard keyboard position). In the first setting, the centres of the two halves were spaced 20 cm apart, in the second indirectly between the standard setting and the shoulder width setting. In the third, the keyboard halves were on the shoulder width and were parallel to each other (Figure 5). Each participant in this study typed for 5

Table 4

Comparison of ergonomic with standard keyboard in the aspect of influence on the occurrence of pain in the upper limbs and shoulder girdle

Source of report	Compared parameters	Standard keyboard	Ergonomic keyboard
Szeto[28]	Activity of wrist extensor muscles (% max conscious contraction)	Brachial rectifier	
		8.1%	7.4%
		Elbow extensor	
		10.5%	9.4%
	Wrist placement	Extension	
		12.7°	5.6°
		Ulnar deviation	
		7.8°	2.5°
Tittiranonda[29]	Pain in individuals with carpal tunnel syndrome or tendonitis	50% – no changes in pain intensity 25% – intensification of pain	43% – improvement in pain 13% – intensification of pain
Marklin[30]	Average wrist ulnar deviation angle	Left hand: 18.9° Right hand: 14.2°	Left hand: 7.0°-8.5° Right hand: 2.7°-5.0°

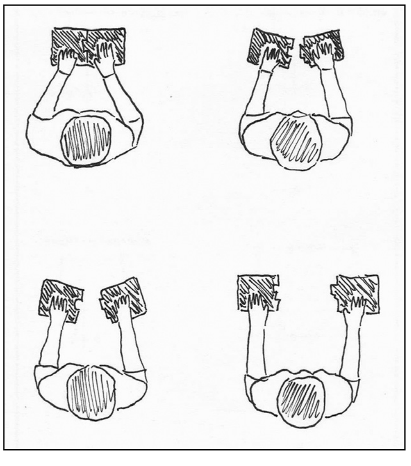

Figure 5
Placement of keyboard during the study[30]

minutes on all four keyboards. All settings of the alternative keyboard showed a much smaller average deviation of the wrist as compared to the standard keyboard. In addition, there was no significant slowdown in typing when using the alternative keyboard. The authors of this report, analysing the results obtained using the Borg scale for load-exposed parts of the body, found differences only in the case of the cervical segment for all the keyboards used. Pain discomfort assessment for the users of the standard keyboard was higher than for those using the three alternative keyboard settings. There were no significant differences between the variables tested between these settings.

Smartphone touchpads

Yang et al.[31] examined the effects of using smartphones on the occurrence of musculoskeletal pain among students, mainly within the spine and shoulder girdle. In total, 302 questionnaires were analysed. It turned out that most students (77.2%) typed on the phone more than an hour a day. The use of smartphones resulted mainly in neck pain, which was noted in 52% of respondents, shoulder pains, which occurred in 46.6% of them and lower back pain.

An electromyographic examination during typing on a smartphone keyboard was conducted by Lee et al.[32]. They compared the tension of three muscles while performing one- and two-handed typing – of the upper part of the trapezius, extensor pollicis longus and abductor pollicis longus muscles. After that the authors of the examination also used a dolorimeter to measure the pain threshold of the trapezius muscle. It turned out that the examined muscles were much more tense when writing one-handed ($p < 0.05$). Using a smartphone also contributed to the increase of muscle sensitivity to pain.

Inal et al.[33] conducted a study on 66 smartphone users typing one-handed, including 32 of whom type rarely and 34 of whom type frequently. The results obtained by the authors of this study were compared with the results

Table 5

The influence of using smartphones on the occurrece of upper limb and shoulder girdle pain

Source of report	Research method	Location of pain/discomfort	Cause of pain
Yang[31]	Questionnaire	Neck, shoulders	Prolonged phone usage (>1h/d)
Lee[32]	EMG	Possible trapezius, extensor pollicis longus and abductor pollicis muscle pain	Increased muscle activity during typing, especially one-handed
Inal[33]	USG, dynamometer	Thumb, wrist	Prolonged phone usage
Qasim[34]	Questionnaire	Thumb	Prolonged phone usage

recorded for people who do not use personal phones. Dynamometer and graphically recorded ultrasound examination of the wrists were used for the study. Based on this methodology, the study found that overuse of smartphones increases the cross-section of the median nerve and aggravates the related thumb-pain and weakening of hand grip strength. Another study by Qasim et al.[34] confirms that excessive use of smartphones can lead to the appearance of thumb pain. The study was carried out using a questionnaire on 300 people using this type of phone with one or both hands. In the majority of respondents in this project, the authors noted distinct pain in various parts of the thumb. Most participants of the study experienced pain related to different parts of the thumb.

Table 5 presents the results of the particular tests.

DISCUSSION

The problem of pain in the upper limbs, shoulder girdle or spine related to work as well as to the use of computers during work, is widely known in the thematic literature and professional practice of doctors and physiotherapists[35-37]. The incidence of many diseases, e.g. of carpal tunnel syndrome, has significantly increased in many populations since the increase in importance and use of computers in everyday life[38]. The aim of this work was to analyse the threats resulting from the use of computer keyboards and smartphones. After analysis of the thematic literature from the last 18 years, only 13 papers assessing the influence of different types of keyboards on the occurrence of pain in the upper limbs, shoulder girdle and cervical spine were identified, with only being randomized clinical trials. As it would seem, from the two only the study by Tittiranond et al.[29] may be relevant for clinical practice; one of the arguments in favour of the paper is that it had been conducted on a large group of respondents. 80 people were included in the study, and divided into a study group and three control groups with a population of 20 people each. As for the paper by Rempel et al.[26], studies with similar thematic characteristics were carried out on a group of only 20 people, which may raise objections regarding their credibility. Similar objections may be raised against the studies by Szeto et al.[27], who in the choice of research methodology did not take the necessity of random division of the study group into account.

The analysed specialist literature concerned various methods of research and interpretation of its results, which definitely hinders a reliable comparison and unambiguous determination of the impact of typing on various keyboards on the musculoskeletal structure of the shoulder girdle, cervical spine and the hand.

Gerard et al.[25], Rempel et al.[26] and Szeto et al.[27] all investigated the impact of the pressure force on the computer keyboard keys on selected upper limb muscles. For this purpose, Gerard et al.[25] and Szeto et al.[27] measured the activity of these muscles while typing, however, they studied other muscles. Rempel et al.[26], on the other hand, studied the intensity of pain in people with paraesthesia of the hands. In each of these tests, a different selection of keyboards was also used. Gerard et al.[25] used 4 similar keyboards differing in the pressure needed for pressing the keys. Rempel et al.[26] used two types of keyboards that differed in their required pressure force and key placement. Finally, Szeto et al.[27] chose one standard keyboard, on which the respondents increased the pressure force exerted on the keys. Despite the obvious difficulties in making a reliable comparison of the results of these tests, it can be assumed that the stiffness and placement of individual keys has significant impact on the pain in the upper limb and shoulder girdle arising in this mechanism.

The studies on the influence of using a standard keyboard on the functions of the median nerve during typing on a standard keyboard were also significantly different in the analysed scientific reports. Toosi et al.[1], to this end, performed after 60 minutes of typing on this type of keyboards ultrasound images of the examined wrist bones, on the basis of which they determined the changes in their cross-section. Rempel et al.[14], on the other hand, used a so-called catheter to determine the pressure in the wrist canal of people typing on standard keyboards. This method allowed the authors of the report to adopt a thesis that the studied activity has a negative effect on the functions of the median nerve.

Based on a review of professional literature regarding the impact of using ergonomic keyboards on the functionality of the shoulder girdle and upper limb, it can be concluded that the comparison of results obtained by many authors is difficult, and impossible from the point of view of methodological accuracy. Only the research published by Szeto et al.[28] and Marklin et al.[30] provide such an opportunity, because they were carried out on a group of healthy people. On the other hand, the study by Tittiranond et al.[29] were based on a group of patients with carpal tunnel syndrome and tendinitis of the muscles. In addition, Szeto et al.[28] as well as Marklin et al.[30] studied the angle of the ulnar deviation of wrists when typing on both standard and ergonomic keyboards. Their results differ slightly (Table 4). It seems that this may be due to the difference in time frame assumed for the recommended writing activity. Nevertheless, those typing on a standard keyboard recorded higher angular values of the ulnar deviation than those using an ergonomic keyboard[28-30]. Not all of the analysed studies took into account in the characteristics of the adopted methodology the technological aspects of the construction and mechanism of keyboard keys, which, according to Gerard et al.[25] and Rempel et al.[26], may be important for their credibility.

The most up-to-date items of professional literature concerning the issues discussed, dating from 2015 to 2017, were not based on the necessity of randomization, and thus did not meet the criteria for inclusion in the present analysis.

Three articles: Yang et al.[31], Inal et al.[33] and Qasim et al.[34] have some similarities because they investigated the occurrence of various ailments in people overusing smartphones, while Lee et al.[32] measured muscle activity while typing on this kind of phone, which is why the latter escapes comparison with the other studies.[32-34] Having analysed the collected professional literature one can adopt the thesis that excessive and frequent writing on a smartphone keyboard clearly generates pain in the shoulder girdle and upper limbs differing in clinical expression, frequency of occurrence and character. Unfortunately, there are no scientific reports determining the effect of the analysed motor activities on the functionality of selected structures of the musculoskeletal system.

SUMMARY

Analysis of the considered professional literature allows undoubtedly to adopt the thesis that using keyboards with different technological and ergonomic characteristics, including tactile characteristics, initially increases the activity of the hand and forearm muscles. However, the activity is connected with the necessity of performing precise movements repeatedly, which over time, causes overloading of these muscles and has negative impact on their functionality, causing also certain pain in the hands, forearms and shoulder girdle. Due to the individual conditions of the presence of overload syndromes of the musculoskeletal system, the selection of an appropriate keyboard to use with selected electronic devices should also be individual. At the moment, ergonomic keyboards seem to be a more favourable choice. Functional efficiency of the musculoskeletal system of the shoulder girdle and upper limbs during typing is undoubtedly negatively affected by its speed, the pressure exerted on keyboard keys (resulting mainly from their technological characteristics) and the long-lasting, forced position of the hands and wrists. It also seems that research on the presented issues should be based on larger study groups, and certainly include undeniable standards of scientific research.

CONCLUSIONS

1. Using the keyboards of selected electronic devices with diverse ergonomic characteristics, has an adverse effect on the functionality of the shoulder girdle and upper limb, generating painful symptoms with different clinical characteristics.
2. The most important influence on the occurrence of functional disorders and pain in the shoulder girdle and upper limb while using keyboards with different ergonomic characteristics is the pressure force exerted on the keys, typing speed and long-lasting, forced position of the wrists and forearms.

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