

BABY WALKERS AND THE PHENOMENON OF TOE-WALKING

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Received: 14.03.2017

Accepted: 16.02.2018

Background. There is limited data in the literature regarding the clinical impact of baby walkers (BW's).

Aim. In this study, we examined the hypothesis that the formation of abnormal motor pattern in the form of preferred moving without support on the heel, while using a BW.

Objectives. We aimed to determine certain epidemiological impact of the use of infant walkers in order to identify the toe-walking pattern to determine the accuracy of its connection with the walker for estimating the volume and characteristics of the phenomenon.

Methods. Three retrospective cohort studies were conducted. All the children included in the sample ($n = 749$) and 363 infants used BW's. Method selected anamnestic survey of parents on a specially designed, anonymous questionnaires and statistical analysis of data.

Results. The study population had been using BW's for several years. The reasons for the use of infant walkers were identified. The relative risk of walking without heel support in the BW's user groups $RR_2 = 3.555$ (2.535–4.990, 95% CI) and $RR_3 = 2.766$ (1.178–6.494, 95% CI) was calculated for the second and third studies, respectively. There was an increase in the correlation between toe walking and the use of BW's with longer duration of use. The risk of toe walking in the BW user group ($PAR = 19.647\%$) was calculated. The study revealed no static deformation associated with the use of BW's.

Conclusion. The use of BW's was identified as a factor contributing to the formation of the toe-walking pattern and as a possible causal factor of idiopathic toe walking.

Keywords: baby walkers; infant walkers; toe walking; idiopathic toe-walking (ITW); gastrocnemius-soleus complex; BW's users.

ДЕТСКИЕ ХОДУНКИ И ФЕНОМЕН ХОДЬБЫ НА НОСКАХ

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Статья поступила в редакцию: 14.03.2017

Статья принята к печати: 16.02.2018

Актуальность. При обзоре исследований выявлен малый объем данных о возможном влиянии ходунков на формирование паттерна ходьбы на носках.

Гипотезы и цели исследований. В работе рассмотрена гипотеза о формировании аномального двигательного паттерна в виде предпочтительного перемещения без опоры на пятку при использовании детских ходунков. Цель исследования — определение ряда эпидемиологических аспектов использования ходунков, выявление аномального паттерна ходьбы на носках, определение достоверности его связи с ходунками, оценка особенностей явления.

Материалы и методы. Было проведено три ретроспективных когортных исследования. В выборки включено 749 детей; количество детей в «ходунковых» группах составило 363. В качестве методов выбраны анамнестический опрос родителей по специально разработанным анонимным вопросам и статистический анализ данных.

Результаты исследований. Определено снижение использования ходунков в популяции в течение нескольких лет. Установлены причины использования детских ходунков. Рассчитан относительный риск ходьбы без опоры на пятку в «ходунковых» группах: $RR_2 = 3,555$ (2,535–4,990 95 % ДИ) и $RR_3 = 2,766$ (1,178–6,494 95 % ДИ) для второго и третьего исследований соответственно. Выявлен более продолжительный период ходьбы на носках в «ходунковой» группе: $M_{ген.} = 14,58 \pm 3,49$; 11,09–18,07 мес. (95 % ДИ). Установлено увеличение корреляции между ходьбой на носках и ходьбой при помощи детских ходунков при большем времени их использования.

Был рассчитан популяционный риск ходьбы на носках в «ходунковой» группе: $PAR = 19,647\%$. В работе не выявлены статические деформации, ассоциированные с использованием детских ходунков.

Заключение. Детские ходунки определены как фактор, способствующий формированию паттерна ходьбы на носках. Возможно, ходунки являются этиологическим фактором идиопатической ходьбы на носках.

Ключевые слова: детские ходунки; ходьба на носках; идиопатическая ходьба на носках (ИХН); икроножно-камбаловидный комплекс.

Introduction

In the modern world, an individual is affected not only by natural factors, but also by the significant influence of the anthropogenic environment. This influence starts to exert itself on an individual since infancy via the use of various adaptations, such as cots with electronic components, developing mats, automatic rockers, and “jumperoo.” Here, we present data on the study of certain aspects of the impact of a device called “baby walker.” The issue regarding the influence of baby walkers on babies has repeatedly been investigated by the world scientific community; however, information regarding its negative impact has not been assessed in sufficient detail.

Modern baby walkers are wheel-based technical devices that hold the child in an upright position. The exact time of introduction of baby walkers in this form is unknown. However, the first patents for the improvement of baby walkers were in the 1980s [1, 2].

Baby walkers are used by parents worldwide owing to several reasons. Researchers from Dublin (Ireland, 1995) reported that 55% of the 158 infants were used to staying in similar devices for some duration. The main indicated reasons included positive emotions of a child and the experience of early use in older children [3].

According to a survey in the USA (Virginia, 1998), parents used baby walkers for 77% of the 119 first-borns and 85% of the second and subsequent children. Furthermore, 78% of the respondents believed that walkers were useful and 72% of them expected the baby walkers to help child development [4]. In Austria (1994), the interviews of families with children aged 2–6 years revealed that 55% of the 240 respondents used walkers [5].

In the UK (Nottingham, 1998), 55% of the parents of the 2,152 enrolled children purchased the walkers [6].

In a study performed in Iraq (Baghdad, 2006), 83% of the 100 infants (44% girls and 39% boys)

used devices, during a period of 5–8 months. The reasons provided for the use included “to amuse the child” (71%); “to teach to walk earlier” (54%); and “to strengthen the legs” (28%) [7].

A study performed in the United Arab Emirates (2015) showed that 90% of the 619 families used walkers. In 92%, the child’s safety was cited as a reason for using them [8].

The study regarding the direct influence of baby walkers on the structure of walking in medical science first started in 1977 in New Jersey (United States of American [USA]) with the research of doctors I.R.A.B. Kauffman and M.V. Ridenour [9]. Electromyograms of the lower limbs of 6 pairs of homozygous twin boys were studied. Based on the study results, the authors concluded that the walking structure of the “walker” and “non-walker” children was significantly different; therefore, the positive effect of using the walkers appeared questionable.

Thereafter, in 1999, Dr. A.C. Siegel and R.V. Burton addressed this issue partially in their study conducted in New York [10]. They analyzed the motor skills and mental development of 109 children to find that the “walker” infants sat, crawled, and walked later than those in the control “non-walker” group; moreover, the “walkers” scored lower on the Bayley Scales of Infant Development (BSID). The authors concluded that the risks of using walkers outweighed the advantages.

In keeping with the above problems, so-called idiopathic toe-walking (ITW) has been studied worldwide [11] since the late 1980s. [12–14]. Considering the studied topic, R.H.H. Engelbert et al. mentioned the possible connection between baby walkers and ITW in 1999 [15]. Similar observations were made in subsequent researches [16, 17]. However, the study by P. Martín-Casas et al. that was published in September 2017 showed no significant causal effect of walker use on ITW [18].

Limited data are available in the literature regarding this subject. The change in the structure

of motor skills is discussed directly only in one observation, and only one report discusses two cases of gastrocnemius muscle contracture and a condition that imitates spastic diplegia. Considering the structure of the study data and the reports of 6 twins and two patients [9, 15], the results obtained can be interpreted as unclear and warrant further clarification.

Our own literature review and the above-mentioned reasons confirm the necessity for additional study of this problem.

Hypothesis and study aims

As per modern theories, the prevailing hypothesis is the formation of motor skills in the form of an initial “primitive” pattern of muscular activity, preserved, perfected, and supplemented with new elements with its development [19].

Based on empirical observations, we proposed a basic hypothesis that walkers violate the natural process of forming a habit of independent walking both in time and structure. This is attributable to the exponential learning and development of locomotion that occurs using the walker, different from that in ordinary walking. The effect of walkers has several potential application points.

The first moment is a relatively rigid fixation in the device that interferes with the proper dynamic control of balance.

The second moment can be considered an obstacle to the visual control of lower limb movements that affects the pyramidal-strial level because as per N.A. Bernstein, “sensory correction of this level ensures the coordination of the motor act with the outer space with the leading role of visual afferentation” [20].

In P.I. Ivanenko’s studies, it was established [19, 21] that the special aspect of vertical movements of the pelvis (as a point of the center of mass) during the period of walking formation is the absence of a characteristic first peak in the diagrams, indicating the absence of a pronounced “pendulum” nature of the center of mass movement in the support phase. Consequently, in the second phase, that of leg straightening, when the support reaction declines (its minimum is indicated at the end of the phase), the rise of the common center of mass is less pronounced than in an adult. In the third phase, the tibial inclination forward, at

the time of development of the posterior thrust, the overall decrease in the center of mass, when the muscles function inferiorly, is less pronounced or absent. With the use of walkers, the decrease in the center of mass is further limited by their design (the presence of a “gazebo”); further, the horizontal, partially passive movement is limited by overcoming the frictional forces in the wheel system of the device. We believe that this increases the load on the gastrocnemius-salens complex of the lower leg.

Another interesting feature was revealed by Yu. P. Ivanenko [22]. In a child, at the time of unloading of body weight, lifting of a foot during a phase of transfer decreases significantly, and movements of the leg are similar to pendulum movements with noticeable forward projection of the leg. Further, the child thus has a tendency to walk without resting on the heel. Similar “unloading” occurs during the use of baby walkers, wherein the child is “suspended” in a holding gazebo.

Thus, when walkers are used during the second and third phases of the double step, there is increased load on the muscles-extensors of the foot; further, during the transfer phase, there is a tendency to support on the forefoot. We believe that as per the classical concept of the dominant and dynamic stereotype, in total, this contributes to the formation of an abnormal motor pattern in the form of a preferred movement without heel support or toe-walking. Moreover, the load change may cause various acquired static foot deformities.

These changes are reversed during ontogeny; however, this requires some time. Therefore, independent locomotion is delayed [23], its structure changes. The phenomenon of walking on the toes may continue for certain duration, and the hypertrophy of the gastrocnemius-salens muscles can be expressed before the imitation of the spastic diplegia of the lower limbs, noted in a report by Dr. R. H. H. Engelbert et al. [15].

Three studies have investigated the various aspects of the influence of baby walkers. Here we analyzed the data related to movement without heel support. From this position, the study aimed to identify the various epidemiological aspects of walker use, identify the phenomenon of walking on toes, determine the reliability of its connection with the use of walkers, and evaluate the features of the phenomenon.

Definition of concepts

Walking on toes (WT XH) is movement when the child moves on two legs without heel support for more than 5 consecutive steps, with repetitions for 1 week, when he/she is learning to walk. Rising on toes without movement is not considered WT XH. The term was introduced to integrate a phillistine assessment of the state in a survey and for our understanding of a hypothetical abnormal locomotor pattern. Foreign literature defines it with the term “tip-toe-walking” or, more often, toe-walking.

In the studies, we introduced the index of *walk-er-day* (w/d) that defined the stay of a baby in the walker for 1 h every day for a month. This term replaces the term “aggregated h (day) of the use of walkers,” a term that conveys the same meaning but is more awkward. Furthermore, the dimensionality of this variant is reduced; this facilitates calculations. The term is similar in structure to the term “pack-year” that is used in large-scale observational studies conducted by the World Health Organization (WHO) on the danger of smoking.

Example: 30 min per day for 1 month is 0.5 w/d; 2 h a day for 3 months is 6 w/d; and 6 h a day for 5 months is 30 w/d.

Materials and methods

Three retrospective cohort studies conducted in the children’s polyclinic of the State Budgetary Healthcare Institution Rzhevskaya Central Republican Hospital and four Municipal Preschool Educational Institutions of the city of Rzhev (Tver region) were reviewed. The total number of children in the study sample was 749; the “walker” group included 363 children.

The first study was titled, “Epidemiological aspects of the use of walkers and correlation with the valgus placement of feet.” Data were collected from February 2016 to September 2016 for children born from January 2015 to September 2015 in Rzhev (Tver region). Total 468 children were born during the registration period, and 284 (57.14%) were at the appointment. Patients whose parents were unable to accurately indicate the necessary data and those with severe congenital pathologies ($n = 16$) were excluded. Total 268 children aged 11–18 months were enrolled; the study sample comprised 133 (49.63%) girls and 135 (50.37%) boys. Research methods included anamnestic polling of parents using a standardized, specially developed anonymous questionnaire and an objective assessment of the feet deformities. The results are presented in Table 1.

The grouping was performed as per the use of baby walkers; in addition, the sex composition, reasons for using such devices, “walker” damage, and valgus placement of feet were also considered.

The second study was titled, “Influence of baby walkers on the development of motor skills in infants.” Data were collected from September 2014 to September 2015. The assessment included all the infants who were healthy at the time of the visit, those who underwent a preventive examination of the 1st year conducted by an orthopedic traumatologist, and those who were born from September 2013 to September 2014 in Rzhev (Tver region). Patients with motor impairment caused by locomotor or nervous system diseases, congenital or acquired hypotrophy, and children whose parents could not accurately indicate the required data were excluded. No sex-based division was made. Total 514 children were born during the registration period; 408 (79.3%) were at the appointment, and 358 (69.6%) were

Table 1

Registration form of the study

Indicators	Ser. No			
	1	2	...	10
Period of use				
Usage per day				
Age				
Sex				
Reason for use				
Presence of valgus placement of feet, other pathologies				

Table 2

Registration form of the study

Indicators	Ser. No			
	1	2	...	10
Age (months)				
Diagnosis in months 1–3				
Standing at the support from... (month)				
Walking with support from... (month)				
Independent walking from... (month)				
Toe-walking (yes/no)				
Using the walkers (yes/no)				
Min per day (in walkers)				
Total days (in walkers)				

Table 3

Results of the questionnaire survey

Indicators	Ser. No			
	1	2	...	10
Date of birth of the child, sex				
Diagnosis of a surgeon or orthopedist (if any)				
The presence of toe-walking (yes/no)				
if yes, till what age (months)				
Usage of walkers (yes/no)				
Additionally: any abnormalities of walking and lower extremities indicated by parents (e.g., “clubfoot,” “cross-shaped legs,” etc.) (if any)				

included in the sample at the age of 11–15 months; the “walker” group included 182 (50.84%) children. The method used was anamnestic polling of the parents using a standardized, specially developed anonymous questionnaire. The data were recorded by a specialist doctor and are presented in Table 2.

Interval (according to the index of the walker-day) grouping of children who performed toe-walking was performed.

The third study was titled, “Baby walkers and toe-walking.” Data were collected from April 2016 to July 2016 based on the four municipal preschool educational institutions of Rzhev (Tver region). Data were recorded via anamnestic polling of parents according to a standardized, specially developed anonymous questionnaire. The results were recorded by medical specialists and are presented in Table 3.

Total 180 parents were asked to answer the questions. The study excluded children whose parents could not accurately indicate the necessary data.

One hundred and twenty-three respondents agreed to answer the questionnaire and provided accurate data. Baby walkers were used for 64 (52.03%) babies. The sex composition of the sample was as follows: 53 (54.31%) girls and 63 (45.69%) boys. The age of the enrolled children ranged from 18–41 months.

Grouping was performed regarding the use of baby walkers and toe-walking.

All data were evaluated using various methods of statistical analysis.

All calculations were performed using Microsoft Excel®, IBM® SPSS® Statistics and the online calculator of the sites <http://app.statca.com>, <http://medstatistic.ru> and <http://www.semestr.ru> on IBM-compatible computer with the installed Microsoft Windows 10® operating system.

In all the studies, two systematic errors were identified. The first was the population bias introduced because the sample was represented by

the children belonging to the Caucasoid race with an unrecorded ethnic composition (conditionally adopted close to that of the Central Federal District of Russia). The second was a recall bias that was related to the structure of the study and the anamnestic polling.

All the parents or guardians voluntarily signed informed consent for study participation.

Results

The complete data of the three studies is presented in Figure 1. The diagram shows a marked decrease in the use of walkers in the population over time.

We used the data from the first study to understand the reasons for using baby walkers. The answers (117) given by the parents were taken in the free form; however, they could be categorized into three groups (Figure 2).

As shown in the diagram, only 40.17% of the respondents in Rzhev used walkers to enable better child development. Majority (57.26%) of them

stated that walkers were a means “to amuse the child” safely, and many parents stated that the use of walkers provided the opportunity for them to “do their own duties.” In addition, some respondents reported their awareness regarding the danger involved in using such devices.

It should be remembered that hypothetically, when using the walkers, the formation of an abnormal motor pattern in the form of a preferred movement without heel support is possible. In the second and third studies, more children in the walker group walked on their toes. To evaluate the availability and reliability of the connection, four-field tables were constructed and analyzed.

- In the second study (group with HN-144), the following associations were revealed:
 - statistically significant relatively strong connection ($p < 0.01$);
 - relative risk (RR) of toe-walking = 3.555 (2.535–4.990 for 95% confidence interval [CI]);
 - risk difference (RD) 0.450.

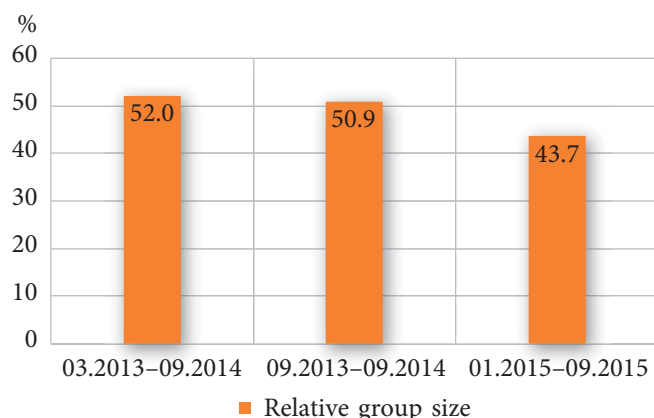


Fig. 1. The proportion of “walker” groups according to three own studies. Grouping by date of birth

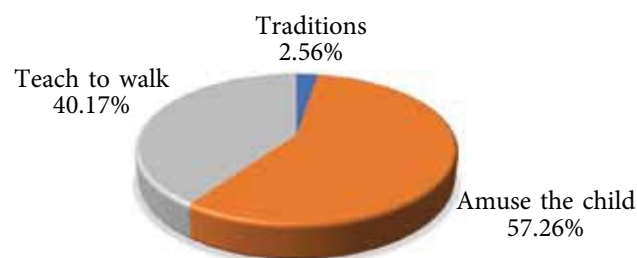


Fig. 2. Reasons for using baby walkers as per our study



Fig. 3. A box diagram of the ages at which toe-walking stopped in the “walker” and “non-walker” groups

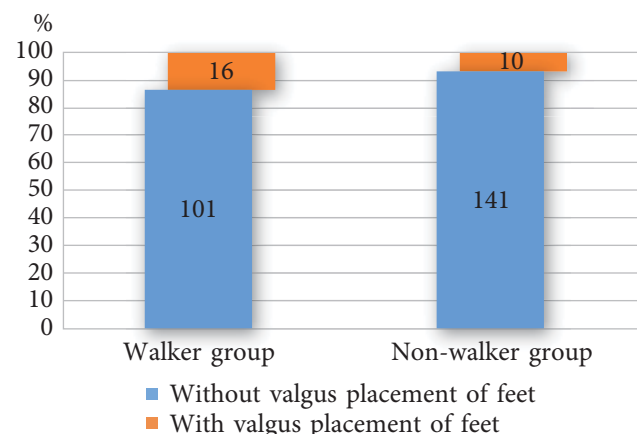


Fig. 4. Proportion of children with the acquired valgus placement of feet in groups

- In the third study (group with HN-18), the following associations were revealed:
 - statistically significant mean strong connection ($p < 0.01$);
 - RR of toe-walking = 2.766 (1.178–6.494 for 95% CI);
 - RD 0.18.

The marked difference between the results is attributable to the smaller representativeness of the sample in the third study (wider confidence interval, smaller sample size [$n = 123$], and lower accuracy of the anamnestic data). Consequently, less accurate data were obtained. Therefore, in assessing the phenomenon, the results of the second study were more accurate. Thus, it can be argued that a “walker” child is approximately 3.5 times more likely to toe-walk periodically.

The third study naturally established a longer period of walking without heel support in the “walker” group than in the “non-walker” group. This was confirmed by calculating the mean values and comparing them using statistically valid methods. The results of the Student’s t -test and the Mann-Whitney U test showed the following:

- average values for these groups:
 M gen. (in the walker) = 14.58 ± 3.49 ; 11.09–18.07 months (95% CI);
 M gen. (without walker) = 13 ± 2.1 ; 10.09–15.1 months (95% CI);
- Student’s t -test $t = 2.61$; $p < 0.05$. The Mann-Whitney U test is $U = 58$; $p < 0.01$. The resulting levels of error probability (p -value) were less than the acceptable value; therefore, the statistical differences were significant.

For clarity, a box diagram was constructed (Figure 3).

In the second study, the χ^2 criteria and Pearson conjugation coefficients were calculated for individ-

ual intervals of the w/d index (the most representative ones were chosen). The correlation between toe-walking and use of walkers increased with a higher duration of use of the walkers (Table 4).

Based on the prevalence of the use of baby walkers in the samples of all three studies, an additional (attributive) population risk of toe-walking was calculated using the data on the $RD = 0.425$ obtained in the second study:

- for the first study (children born from January 2015 to September 2015), the “walker” group was 117 (43.66%), $PAR = 19.647\%$;
- in the second study (children born from September 2013 to September 2014), baby walkers were used in 182 (50.84%) infants, $PAR = 22.878\%$;
- in the third study (children born from March 2013 to September 2014), baby walkers were used in 64 (52.03%) children, $PAR = 23.4135\%$.

It should be remembered that owing to the special aspects of the samples used for evaluating this phenomenon, the results of the second study appear more accurate. Thus, the population risk of toe-walking caused by the use of walkers was 19.647%.

V.A. Mickiewicz points out, “The background for the development of planovalgus deformity... is an increase in the load on the limbs, associated with learning to walk” [11]. We hypothesized that in the early stages, the additional load while walking in the walkers could manifest itself as static feet deformities. An attempt to identify such possible consequences of the use of walkers in the first study was unsuccessful. The only established pathology in the sample was the acquired static valgus deformity of the feet that accounted for 27 cases (of the total 268 cases, 10.07%). The distribution of the pathology in the two groups is shown in Figure 4.

Table 4

The values of the χ^2 criterion and the Pearson conjugation coefficient (C) for different walker-day intervals

Walking-day interval	Criterion χ^2 at $p < 0.01$	Pearson conjugation coefficient (C) at $p < 0.01$, correlation relationship intensity
0.125–0.16	15.686	0.280 average
0.125–0.25	30.573	0.363 relatively strong
0.125–0.375	41.476	0.408 relatively strong
0.125–0.75	51.093	0.416 relatively strong
1–30	63.768	0.425 relatively strong

Table 5

Four-field table for assessing the baby walkers as a factor contributing to the valgus placement of feet

Indicator	Valgus placement of feet	Norm	Total
In walkers	16	101	117
Without walkers	10	141	151
Total	27	241	268

The diagram shows the prevalence of this pathology in the “walker” group. To verify the statistical reliability of the connection of these phenomena, we constructed a four-field table (Table 5).

The four-field table was analyzed; the obtained criterion of the χ^2 -square was 3.743 for $p > 0.05$ (with the Yates correction of 2.981, $p > 0.05$). Such an error probability level (p -value) exceeds the acceptable level, indicating no statistically reliable connection. Accordingly, the impact of baby walkers in this study was random. Thus, we can conclude that no static deformities associated with the use of baby walkers were found.

Conclusion

Toe-walking since the beginning of independent walking has been documented in the foreign literature [24–29]. It is generally accepted that ITW, as a syndrome, is established in children >2 –3 years of age, before which, such a pattern is regarded a norm [30]. Generally, ITW is distinguished from several orthopedic and neurological diseases, primarily congenital shortening of the Achilles tendon and spastic diplegia [25, 27, 29, 31]. Some authors have suggested that ITW represents minimal cerebral dysfunction [25, 26, 29]. There is also an association with deviations in the emotional sphere and development of cognitive functions [25, 32, 33], complications of the perinatal period [14, 25, 27].

Currently, the concept of ITW is a diagnosis of exclusion, with the etiological factors not being fully identified. Functional disorders are manifested by a slight retraction (contracture) of the gastrocnemius-salens [29, 34–36]. Considering the proposed hypothesis, it may occur because of hypertraining of the foot extensor in the “walker” children.

As indicated above, P. Martín-Casas et al. did not find a statistically significant effect of the walker on ITW [18]. However, our data clearly demonstrated the influence of walkers in terms of increase in

the prevalence of similar locomotor patterns in children. However, we believe that this can be treated using either of the following two methods: either as a phenomenon of “walker toe-walking,” basically passing by 2–3 years, that is, taking into account the proposed hypotheses, a temporary deviation with a return to normal; or consider baby walkers as an etiological factor of the ITW, however, it will be necessary to limit the age of the end of physiological walking on the toes by 15–18 months.

The increase in the load on the anterior section appears to us as the only primary link of the hypothetical pathogenetic chain that can lead to the formation of the acquired static feet deformities. Despite the likely absence of early consequences, the question remains regarding this effect in the older age groups that may manifest, for example, by the transverse spreading of the feet.

Given the availability of limited reliable data regarding this issue and the consequences of toe-walking, we believe that further research be conducted in this area.

As also recommended by the world scientific community that deals with the problem of baby walkers, we recommend conducting detailed investigations of the consequences.

Contribution of authors:

A.V. Krivova — the concept and design of the first and third studies, data analysis of the third study.

A.N. Sharov — the concept and design of the second study, data analysis of the second study, collection and processing of materials, writing the text.

The authors express gratitude to I.V. Sharova for help in the initial processing of the survey data.

Funding and conflict of interest

There is no conflict of interest.

There is no source of funding.

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