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IDENTIFICATION AND ASSESSMENT OF HAZARDS RESULTING FROM THE STRUCTURE OF THE WHEELED CHILD CONVEYANCES COMMERCIALIZED ON THE POLISH MARKET

Keywords: wheeled child conveyances, safety of use, hazards, testing.

Abstract: Safety of wheeled child conveyances in EU is still unsatisfactory despite the European safety standards that are in force.
Data on safety assessment of conveyances commercialized in Poland have not been documented so far, and they require to be completed with some parameters that may be causing hazards.
The aim of the research was the safety assessment of conveyances on the Polish market. The tests were carried out according to own methodology for 84 conveyances. The test results showed that the majority of conveyances did not meet the safety criteria. They indicated a necessity of design changes in the case of conveyances regarding their stability and mechanical strength as well as an elimination of a child's access to dangerous openings and easy-to-be-detached components.
The conducted tests complement the present knowledge on the safety and ergonomics of wheeled child conveyances and form a basis for continuing the research work on an improvement of their design.

Identyfikacja i ocena zagrożeń wynikających z konstrukcji wózków dziecięcych wprowadzanych na rynek polski

Słowa kluczowe: wózki dziecięce, badania bezpieczeństwa użytkowania wyrobów, zagrożenia.

Streszczenie: Poziom bezpieczeństwa użytkowania wózków dziecięcych na terenie Unii Europejskiej, mimo obowiązujących w tym zakresie norm, jest ciągle niezadowalający.
Dane dotyczące oceny stanu bezpieczeństwa wózków dziecięcych wprowadzanych na rynek polski nie zostały dotychczas udokumentowane i wymagają uzupełnienia, w szczególności w zakresie identyfikacji parametrów powodujących zagrożenia.
Celem badań była ocena bezpieczeństwa wózków dziecięcych pochodzących z rynku polskiego. Badania przeprowadzono zgodnie z opracowaną w tym celu metodyką dla 84 wózków. Wyniki badań wykazały, że większość wózków dziecięcych nie spełniała kryteriów bezpieczeństwa użytkowania. Wskazano na potrzebę zmian konstrukcji wózków w zakresie jej stabilności i wytrzymałości mechanicznej oraz wyeliminowania dostępu dziecka do niebezpiecznych otworów oraz łatwo odłączalnych elementów.
Wyniki przeprowadzonych badań uzupełniają stan wiedzy na temat poziomu bezpieczeństwa i ergonomii wózków dziecięcych oraz mogą stanowić podstawę podjęcia dalszych prac badawczych nad rozwojem konstrukcji wózków.

Introduction

Wheeled child conveyances are used for transportation of babies and toddlers. They are the prams in which a child is conveyed in a laying position, the strollers, where a child is moving in a sitting position, and combined prams, which are the combination of the previous two types. The wheeled child conveyances, apart from infant beds and baby carriers, belong to the children articles, which improper manufacture or use can lead to serious injuries and accidents, including the fatal ones [1–8].

US Consumer Product Safety Commission (CPSC) data show that, in the years 2006 – 2015, a number of reported injuries to children during use of wheeled child conveyances was within the range from 11 100 to 14 000 per year [4, 9–16], which makes 16.5% of all injuries associated with use of children articles [17].

Due to lack of the unified system for collection of data on using wheeled child conveyances in European Union, a detailed number of injuries to children was not specified.

There are the following main reasons of injuries to children: fall out (66.8%), tip over (15.5%), stumble (8.8%), limb entrapment in a conveyance component (5.0%), collision (2.8%), and entrapment in conveyances as a result of damage to its structure, or breaking (1.1%) [18].

Improper structure of wheeled child conveyances or ineffective protection of a child in a seat and leaving the child unattended were the reasons of abovementioned injuries. There are the following components that are especially responsible for injuries to children: ineffective brakes, unblocking of folding mechanisms, loosening of belts and the child restraining system protecting against falling out, the improper size of openings between stationary and moving parts in which fingers can be squeezed, crushed, or even cut off, and legs or the child's head can be entrapped [19].

Wheeled child conveyances should be designed according to the requirements of the safety standards that are in force in a given country – ASTM F833 Standard for USA [20], AS/NZS 2088 for Australia [21], and EN 1888 for European Union [22].

The requirements refer to each part of the conveyance, and they define the criteria in a parametric or descriptive form. The meeting of these criteria enables reducing the potential hazards, including chemical ones, which are related to the materials used in manufacture (the product components, as the toys, may be chewed or sucked by children and they can contact their skin) [23–24]. Materials used in manufacture of wheeled child conveyances should absolutely meet the requirements of REACH regulation, which is in force in EU countries [26].

Results of the project realized in the years 2012––2014 by Swedish Consumer Agency within the PROSAFE Joint Action JA2011 [27] confirmed the risk of hazard due to improper design of wheeled child conveyances. It has been reported that 80% of wheeled child conveyances on the European market (among 51 tested) did not meet the safety requirements of EN 1888:2012 Standard. The Report did not specify the number of conveyances from each country, and the tests were performed on the samples delivered for testing in 2013.

It was only stated that 55% of wheeled child conveyances were manufactured out of European Union, mainly in China and Thailand.

The RAPEX system reported that, in a period from January 2012 to December 2017, 37 dangerous wheeled child conveyances (due to structure parameters) were identified on the European market, ten of them were from Poland [28].

The results of research work realized in KOMAG Institute entitled, "Testing the wheeled child conveyances available on the Polish market" [29], aiming at assessment of safe use of the conveyances placed on sale or available on the Polish market in the years 2012–2018, are presented. The results of tests conducted by the authors were compared with the results of PROSAFE Joint Action JA2011 [27] project as well with notifications of RAPEX system [28]. The final assessment was made on the base of many-years' experience gained by the authors, the specialists of the accredited Laboratory of Material Engineering and Environment in KOMAG Institute, specializing in testing and assessment of children products safety [25].

1. Materials and methods

This research work was realized in seven stages. An algorithm of research work is presented in Fig.1.

Documentation of testing the wheeled child conveyances including measuring charts, photo documentation, and reports from tests conducted according to methods that conform to EN 1888:2012 Standard, were analysed in Stage 1. The tests were conducted according to all requirements of the abovementioned standard or to part of them, which depended on the ordered needs and the test objectives. Assessment of the conveyances design for conformity with the standard requirements was conducted for both wheeled child conveyances placed on sale and for those already available on the Polish market that, based upon the users or market surveillance authorities remarks, required reassessment of safety, by the means of testing.

Documentation of 84 wheeled child conveyances used from a child birth until the child gains weight equal to 15 kg was analysed.

In Stage 2, the child conveyances were divided into the following four groups: A, B, C1, and C2 regarding their equipment used (pram body, seat, car seat). The following division of conveyances was used for interpretation of the test results with regard to their equipment.

The percentage shares of tested child conveyances with different equipment are presented in Fig. 2.

The structure of all tested products was mounted on a folding frame. In the case of products from groups A, C1, C2, the frame before folding required removal of pram body, a seat unit or a car seat, depending on the equipment type.

At Stage 3, after analysis of the conveyances structure, the subassemblies and mechanisms that

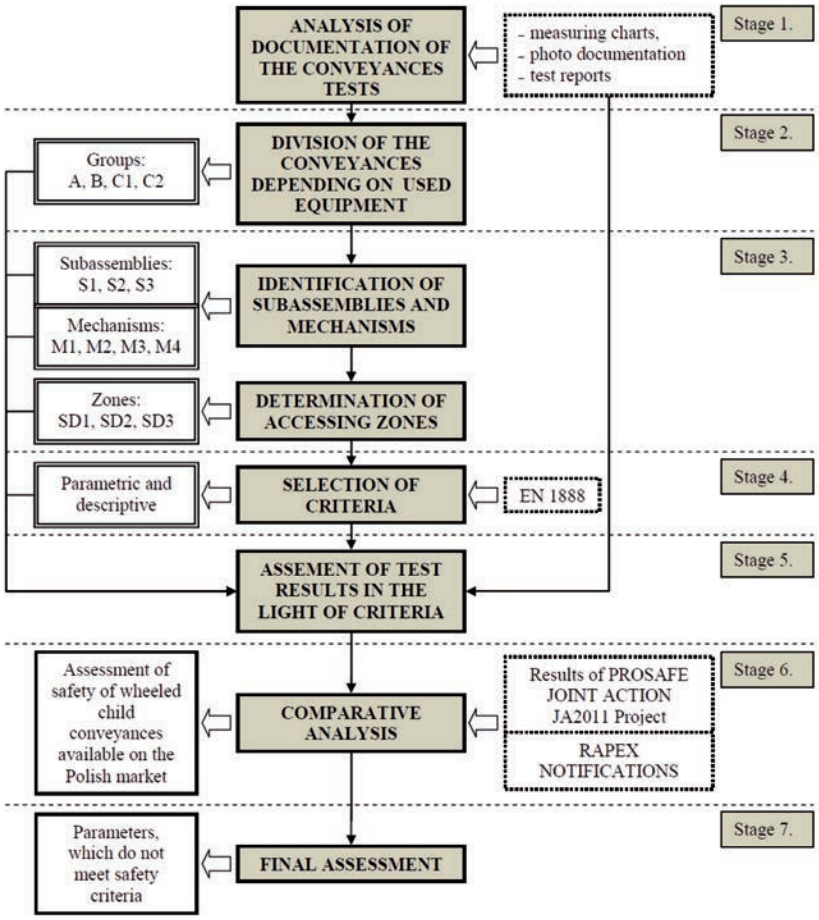

Fig. 1. Algorithm of research work

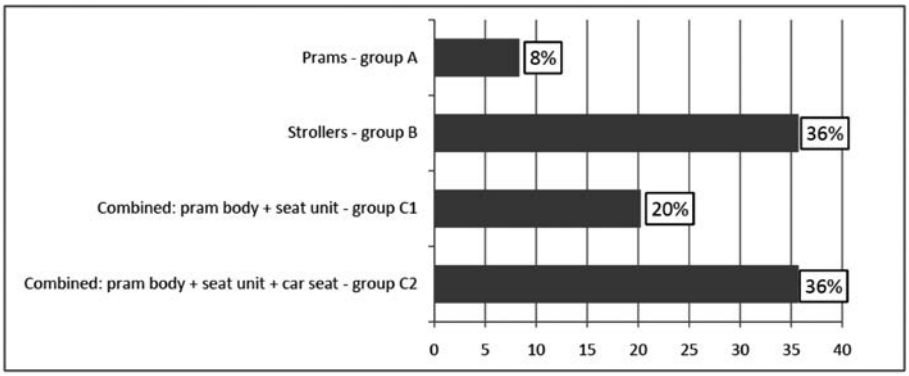

Fig. 2. Percentage share of tested products in each group

impact their safe use were specified and the following child protected volumes were determined: SD1 (pram body of length greater than 800 mm), SD2 (seat unit), and SD3 (pram body of length below 800 mm or car seat). Example position of subassemblies and mechanisms for the conveyances from group C1, with a pram body of length greater than 800 mm, is given in Fig. 3.

Child restraint system S1 as well as push-pull handlebars S2 and also handles for carrying the pram bodies and seat units S3 were the conveyance subassemblies. The following components were classified as mechanisms: parking brakes M1, a device blocking the conveyance frame against folding M2, devices fixing the wheels M3 as well as pram bodies,

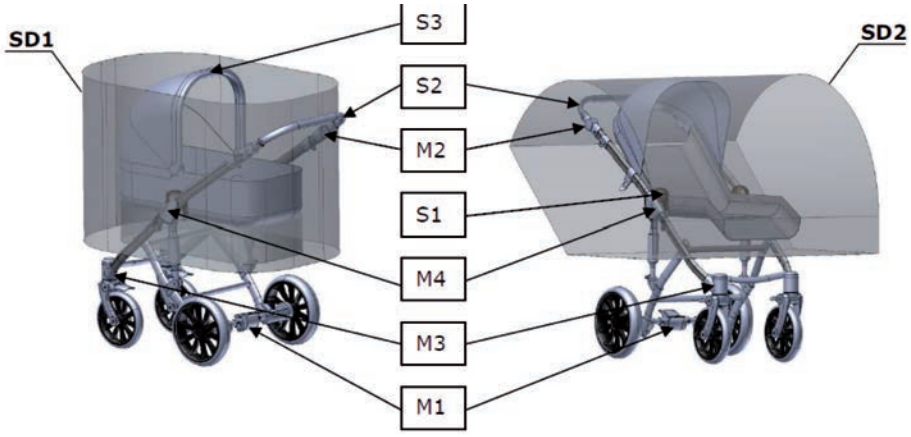

Fig. 3. Position of subassemblies and mechanisms for the conveyances from group C1

seat units, and car seats M4, which are taken off during the conveyance transportation.

At Stage 4, the criteria for the assessment of wheeled child conveyances safety on the grounds of the requirements in EN 1888:2012 Standard were determined, and Tables 1 and 2, specifying the acceptable safety level. The criteria were formulated in a descriptive form (qualitative criteria, specifying the product and its components' conditions required by the standard) or in the parametric form (quantitative criteria). They covered the entire structure of the conveyance, i.e. stability and strength parameters, its equipment – pram body and seat unit or each subassembly and mechanism – Table 1. The criteria were also referred to the conveyance and its equipment components, especially those which were within the child protected volume – Table 2.

Table 1. Criteria for assessment of wheeled child conveyances safety with reference to their equipment as well as their subassemblies and mechanisms

Specification	Tested parameter	Descriptive / parametric criteria
CONVEYANCES STRUCTURE		
Conveyances from A, B, C1, C2 groups	stability	the conveyance should not tip over on the surface inclined at angle equal to 12°
	fatigue strength	lack of damages to the conveyance after travelling on an irregular surface
	dynamic strength	lack of damages to the conveyance after travelling on the surface inclined at angle equal to 10°
	durability of marking	text shall be clearly legible after rubbing with a cotton cloth moistened with water
CONVEYANCES EQUIPMENT		
Pram body in the conveyances of A, C1, C2 groups	internal height	> 150 mm at central line and > 100 mm at side walls, front and rear walls of a single pram body of internal length 800 mm or less
		> 180 mm at central line and > 130 mm at side walls, front and rear walls of a single pram body of internal length > 800 mm
	angle of inclination towards head / foot	< 10 °

Specification	Tested parameter	Descriptive / parametric criteria
Seat unit in the conveyances of B, C1, C2 groups	angle between a seat unit and a backrest	> 150° in the conveyances used from a child birth
		> 95° in the conveyances for babies ≥ 6 months of age
	angle between a seat unit and horizon	> 0°
	angle between a backrest and horizon	> 0°
	backrest length	> 380 mm
	effectiveness of restraint system against fall out	test ball of mass equal to 5 kg should not fall out from a conveyance intended for babies up to do 6 months of age
CONVEYANCES SUBASSEMBLIES AND MECHANISMS		
Child restraint system S1 in conveyances of B, C1, C2 groups	type	crotch restraint system
	width of straps	> 19 mm
	effectiveness of restraint system	a child – dummy D0 (in the conveyances intended for children from birth) / dummy D (in the conveyances intended for children above 6 months of age) should not completely fall out of the restraint system
	strength of attachment devices	no cracks, deformations and loosening after applying force equal to 150 N shall be found
	strength of fasteners	the fasteners shall not be released under action of force equal to 200 N
	effectiveness of adjusting system	maximum slippage < 20 mm
	position of harness anchorage points in pram bodies	in a distance 245 mm from the end of canopy hood to the middle of internal length of pram body on each side of the harness base
	strength of harness anchorage points in pram bodies	no cracks, deformations and loosening after applying force equal to 150 N shall be found
Handlebars S2 for pulling / pushing the conveyances from A, B, C1, C2 groups	durability	lack of damages to the conveyances components/ subassemblies/mechanisms after 10 000 cycles of their lifting and lowering using the handles.
	dynamic resistance	lack of damages to the handles under impact of test mass equal to 15 kg falling from the height 100 mm
Handles for carrying pram bodies and seat units S3 for conveyances of A, B, C1, C2 groups	height of attachment points location	> 0.75 of pram body height
	strength	no damages after loading with test mass equal to 38 kg

Specification	Tested parameter	Descriptive / parametric criteria
Parking bakes M1 in the conveyances of A, B, C1, C2 groups	durability	lack of damages after 200 cycles of operation (braking)
	effectiveness	maintaining the conveyance for 1 min in a stationary position on an inclined surface at angle equal to 9°
	displacement of a wheel or wheels unit	< 90 mm, for the conveyance placed on an inclined surface at angle equal to 9°
Mechanisms locking the chassis against folding – M2 for conveyances of A, B, C1, C2 groups	number of operating devices and actions activating the locking mechanism	− minimum one operating device, not damaged under action of force equal to 50 N or torque 2.2 Nm, requiring minimum two consecutive actions activating the locking mechanism or − minimum two separate operating devices, when both after release automatically return to their original status and activate locking mechanism when intended to be operated by hand(s) or one operating device when intended to be operated by foot or − minimum three independent operating device where one of them is located out of the protected volume or requires a force > 50 N to be operated
	durability	lack of damages after 200 blocking cycles
	effectiveness	lack of damages and no possibility of folding the conveyance under action of a force 200 N on a handle
Device for wheels fixation M3 for the conveyances of A, B, C1, C2 groups	durability	lack of damages after 200 times fitting and removing
	strength	lack of damages under action of a force equal to 200 N
Devices fixing the equipment on the chassis M4 for the conveyances of A, B, C1, C2 groups	number of actions activating the mechanism	− minimum two consecutive actions activating the mechanism, where one of them is continued and the other is undertaken or − minimum 2 independent action at the same time or − more than2 independent actions or
	release force	> 50 N or
	release torque	> 0.34 Nm
	durability	lack of damages after 200 time fitting and removing
	strength	lack of damages to the conveyance turned by an angle equal to 100°

In the case of assessing the stability and strength of conveyances and devices fixing pram bodies, seat units, car seats to the chassis, and the durability of handles, the effectiveness of devices blocking the frame against folding, as well as brakes, safety assessment criteria concerning the conveyances loaded by a mass of the child adequate to its age or to pram body length.

Criterion for the durability of pull/push handlebars did not concern only the handlebars but also the other components/subassemblies/mechanisms, which may affect the safety of their use.

At Stage 5, the results of testing the conveyances from A, B, C1, and C2 groups were analysed in the light of criteria specified at Stage 4. The cases of not meeting the criteria by conveyances, their equipment (pram body, seat unit), and other subassemblies (S1, S2, S3), and mechanisms (M1, M2, M3, M4) were identified. A special attention was paid to the conveyances components and equipment being within the protected volume. Not meeting qualitative and quantitative criteria was identified as exceeding the acceptable safety level.

Table 2. Criteria for assessing the safety of wheeled child conveyances regarding the chassis components and equipment being within the protected volume

Specification	Tested parameter	Descriptive / parametric criteria
Detachable components in the conveyances from A, B, C1, C2 groups	size	detachable components or those, which can separate under torque 0.34 Nm or force 90 N should not fit entirely in the small parts cylinder
		lack of self-adhesive plastic labels
Stationary components in the conveyances of A, B, C1, C2 groups	size of holes / gaps	< 7 mm or > 12 mm (out of the restraint system), in the case of rounded gaps
		< 65 mm or > 223 mm for the gap between the pram body of length greater than 800 mm and pull/push handlebar
		< 7 mm in the case of meshwork
		< 25 mm or > 45 mm for the footrest
Moving components in the conveyances of A, B, C1, C2 groups		> 12 mm between rigid parts moving against each other
		< 5 mm in the case of contact edges of the parts moving against each other
Cords, strings in the conveyances of A, B, C1, C2 groups	length	< 220 mm
	loop circumference	< 360 mm
Edges and protruding parts in the conveyances of A, B, C1, C2 groups	quality of manufacture	no sharp, dangerous edges and protruding parts as well as burrs
		lack of tubes with open ends
Seat unit barriers in the conveyances of B, C1, C2 groups		no availability to the filling material
Pram body and seat unit lining in the conveyances of A, B, C1, C2 groups	thickness	> 0.2 mm, for the plastic lining
	method of manufacture	pulling on in the way protecting against child suffocation in the case of textile lining

At Stage 6, the results of Stage 5 were compared with the results of the PROSAFE Joint Action JA2011 project [27] as well as with the notifications of the RAPEX system [28]. Comparisons were conducted on the basis of data determined by the percentage share of the number of conveyances not meeting required parameters in relation to the total number of tested or notified conveyances. The aim of analysis was the comparison of cases of not meeting the safety criteria by the conveyances, from the Polish market, identified during the tests carried out by KOMAG to corresponding PROSAFE project data and RAPEX notification from European market.

At Stage 7, based on the test results analysis, the conveyances structure parameters, which most frequently did not meet safety criteria and needed improvement in their design, were specified.

3. Results and discussion

In Table 3, the results of wheeled child conveyances analysis made by the authors are presented [30].

Test results proved that majority of the conveyances from group A (over 80%) do not meet safety criteria. In the case of conveyances of other groups (B, C1, and C2), the percentage share of the samples that do not meet the abovementioned criteria did not exceed 71%. The list of the percentage share of the conveyances that do not meet the set criteria in relation to total tested conveyances from groups A, B, C1, and C2 is given in Table 4.

For each tested group of conveyances and the type of parts and their equipment that do not meet safety criteria were specified. Then, for each group, their percentage share in relation to total tested samples was calculated, and the results are presented in a form of a diagram in Fig. 4. The criteria of conveyance structure were assumed as not meeting the safety requirements, when at least one of the detailed parameters (stability,

Table 3. Results of wheeled child conveyances analysis

Sample number	Group of conveyances	Structure of the conveyance	Pram body	Seat unit	S1	S2	S3	M1	M2	M3	M4	Components and equipment within the protected volume						
												Detachable components	Stationary components	Moving components	Cords, strings	Edges and protruding parts	Barriers	Internal lining of a pram body and a seat unit
P1	A	NW	NW	ND	ND	NW	+	NW	+	NW	NW	+	-	+	NW	+	ND	+
P2	C1	NW	NW	-	NW	NW	+	NW	NW	NW	+	NW	NW	NW	NW	NW	NW	NW
P3	C1	-	+	+	+	+	NW	+	NW	NW	NW	+	-	+	ND	+	+	+
P4	B	-	ND	NW	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P5	B	+	ND	NW	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P6	C1	-	NW	-	+	NW	+	NW	NW	NW	+	+	-	NW	+	+	+	+
P7	B	+	ND	+	+	+	ND	+	+	+	ND	+	+	+	+	+	+	+
P8	C1	+	+	+	+	+	+	+	+	+	+	+	-	-	ND	+	+	+
P9	C1	+	+	+	+	+	+	+	+	+	+	+	-	-	ND	+	+	+
P10	A	-	+	ND	ND	NW	NW	NW	-	NW	-	+	NW	NW	NW	+	ND	+
P11	A	-	+	ND	ND	NW	NW	NW	-	NW	-	+	NW	NW	NW	+	ND	+
P12	A	-	NW	ND	ND	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	ND	NW
P13	A	-	NW	ND	ND	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	ND	NW
P14	C2	+	+	-	-	+	+	+	+	+	+	+	-	+	ND	+	+	+
P15	C2	-	+	+	+	NW	+	NW	+	NW	+	+	-	NW	-	+	+	+
P16	C1	+	+	NW	NW	NW	NW	NW	NW	NW	NW	NW	+	+	NW	NW	NW	NW
P17	C1	+	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	+	+	NW	NW	NW	NW
P18	C2	NW	NW	+	+	NW	NW	NW	NW	NW	NW	NW	+	NW	NW	NW	NW	NW
P19	C1	+	+	+	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
P20	C2	+	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	-	NW	NW	NW	NW	NW
P21	C2	+	+	+	+	+	+	+	+	+	+	+	+	NW	+	+	+	+
P22	C1	+	+	+	NW	NW	NW	+	NW	NW	NW	NW	+	-	NW	+	NW	+
P23	C1	+	+	+	+	NW	NW	NW	+	NW	+	+	NW	+	NW	NW	+	NW
P24	B	+	ND	+	+	+	ND	+	+	+	ND	+	-	+	-	+	+	+
P25	B	+	ND	+	+	+	ND	+	-	+	ND	+	+	+	ND	+	+	+
P26	B	NW	ND	NW	NW	NW	ND	NW	+	NW	ND	NW	NW	NW	NW	NW	NW	NW
P27	C2	-	+	-	+	NW	+	NW	+	NW	+	+	-	-	ND	+	+	+
P28	C2	+	+	+	+	+	+	+	+	+	+	+	-	-	ND	+	+	+
P29	C2	NW	NW	+	NW	NW	NW	NW	NW	NW	NW	NW	+	+	NW	NW	NW	NW
P30	C2	+	+	+	+	+	+	+	+	+	+	+	+	ND	ND	+	+	+
P31	C2	+	+	+	+	+	+	+	+	+	+	+	+	ND	ND	+	+	+
P32	C1	NW	+	+	NW	NW	NW	NW	NW	NW	NW	NW	-	NW	NW	NW	NW	NW
P33	B	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	-	-	NW	NW	NW	NW
P34	B	NW	ND	NW	NW	NW	ND	NW	-	NW	ND	NW	+	-	NW	NW	NW	NW
P35	C2	+	+	+	+	+	+	+	+	+	+	+	+	ND	ND	+	+	+
P36	C2	+	+	+	+	+	+	+	+	+	+	+	-	ND	ND	+	+	+
P37	C2	+	+	+	+	+	+	+	+	+	+	+	-	-	ND	+	+	+
P38	C2	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	+	NW	NW	NW	NW
P39	C2	-	+	+	-	+	+	+	+	+	+	+	-	-	-	+	+	+
P40	C2	NW	NW	+	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
P41	B	+	ND	NW	NW	NW	ND	NW	NW	NW	ND	NW	-	NW	NW	NW	NW	NW
P42	A	-	NW	ND	ND	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	ND	NW
P43	B	NW	ND	-	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P44	B	NW	ND	-	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P45	C2	+	+	+	-	+	+	+	+	+	+	+	-	-	ND	-	-	+

Sample number	Group of conveyances	Structure of the conveyance	Pram body	Seat unit	S1	S2	S3	M1	M2	M3	M4	Components and equipment within the protected volume						
												Detachable components	Stationary components	Moving components	Cords, strings	Edges and protruding parts	Barriers	Internal lining of a pram body and a seat unit
P46	C2	+	+	+	+	+	+	+	+	+	+	+	+	+	ND	+	+	+
P47	C2	+	+	+	+	+	+	+	+	+	+	+	+	+	ND	+	+	+
P48	C2	+	+	+	+	+	+	+	+	+	+	+	+	+	ND	+	+	+
P49	C2	NW	NW	+	NW	NW	NW	NW	NW	NW	NW	NW	+	+	NW	NW	NW	NW
P50	C1	-	+	-	-	+	+	+	+	+	+	+	-	-	ND	+	+	+
P51	C2	-	-	-	-	+	-	-	NW	+	-	-	-	-	-	-	-	+
P52	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P53	C2	-	+	-	+	+	+	+	+	+	+	+	-	-	ND	+	+	+
P54	C2	-	+	-	-	+	+	+	+	+	+	-	-	-	ND	+	+	+
P55	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P56	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P57	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P58	B	+	ND	-	+	+	ND	+	+	+	ND	+	+	-	ND	+	+	+
P59	B	+	ND	+	+	-	ND	+	+	+	ND	+	-	-	+	+	+	+
P60	B	+	ND	NW	+	NW	ND	NW	NW	NW	ND	NW	+	+	NW	NW	NW	NW
P61	B	+	ND	NW	+	+	ND	+	+	NW	+	+	-	+	NW	+	NW	NW
P62	C2	-	+	-	+	+	+	+	+	+	+	-	-	-	+	+	-	+
P63	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	+	NW	NW	NW	NW
P64	C2	+	+	+	-	+	+	+	+	+	+	-	-	-	ND	-	-	+
P65	C1	-	+	+	NW	+	+	+	+	+	+	-	-	+	+	+	-	+
P66	B	NW	ND	+	NW	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	NW	NW
P67	C2	+	+	+	+	-	+	+	+	+	+	+	+	NW	+	+	+	+
P68	B	-	ND	NW	+	NW	ND	NW	NW	NW	NW	+	NW	NW	NW	+	NW	NW
P69	B	NW	ND	NW	+	NW	ND	NW	NW	NW	NW	+	NW	NW	NW	+	NW	NW
P70	B	+	ND	NW	NW	-	ND	NW	NW	NW	NW	+	NW	NW	NW	+	NW	NW
P71	B	NW	ND	NW	-	NW	ND	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
P72	B	+	ND	NW	+	+	ND	NW	NW	NW	NW	+	NW	NW	NW	+	NW	NW
P73	B	+	ND	+	+	-	ND	+	-	+	ND	+	-	NW	-	-	+	+
P74	B	NW	ND	NW	NW	NW	ND	NW	NW	NW	ND	NW	+	-	NW	NW	NW	NW
P75	C2	+	+	+	-	-	+	+	+	+	+	-	-	-	+	-	+	+
P76	C2	-	-	-	+	+	+	+	+	NW	+	-	-	NW	+	-	NW	-
P77	B	+	ND	+	+	+	ND	+	+	+	+	-	-	-	NW	-	+	+
P78	C1	-	+	-	+	+	+	NW	+	+	+	-	-	-	+	+	+	+
P79	C1	+	NW	+	NW	NW	NW	+	NW	NW	NW	+	-	-	NW	NW	NW	NW
P80	A	NW	NW	ND	ND	NW	NW	NW	NW	NW	NW	NW	NW	NW	+	NW	ND	NW
P81	C2	-	+	-	-	NW	+	NW	+	NW	+	-	-	-	-	+	-	-
P82	B	NW	ND	NW	NW	NW	ND	NW	NW	NW	NW	NW	+	+	NW	NW	NW	NW
P83	C1	-	NW	NW	NW	NW	NW	NW	NW	NW	+	NW	NW	NW	NW	NW	NW	NW
P84	C1	+	NW	NW	NW	+	NW	+	NW	NW	+	NW	+	+	+	+	NW	+

where: “+” sample meeting the criteria, “-” sample not meeting the criteria, “ND” sample not subjected to the criteria, “NW” not assessed.
Source: Authors.

fatigue strength, dynamic strength, durability of marking) presented in Table 1 was not met.

Table 4. Percentage share of the conveyances which do not meet the set criteria in relation to total tested conveyances from groups A, B, C1, and C2

Conveyances group	Number of tested conveyances	Percentage share of the conveyance not meeting the safety criteria
A	7	86%
B	30	57%
C1	17	71%
C2	30	63%

The analysis of the test results shows that all wheeled child conveyances of Group A do not meet the criteria for their structure, including devices fixing the equipment on the chassis M4 as well as stationary components. The prams do not have sufficient structure strength, and in 60% of them during fatigue tests, while moving on irregular surface, the pram body detached from the chassis, the frame tubes broke in 20% of cases, or the front wheel detached or the tire was damaged. In the bottom of the pram body, dangerous gaps were found, in which the child's fingers could be entrapped. It was found that 67% of the prams did not meet the safety criteria for devices blocking the frame M2 against folding.

Group B wheeled child conveyances did not meet the safety criteria for stationary and moving components.

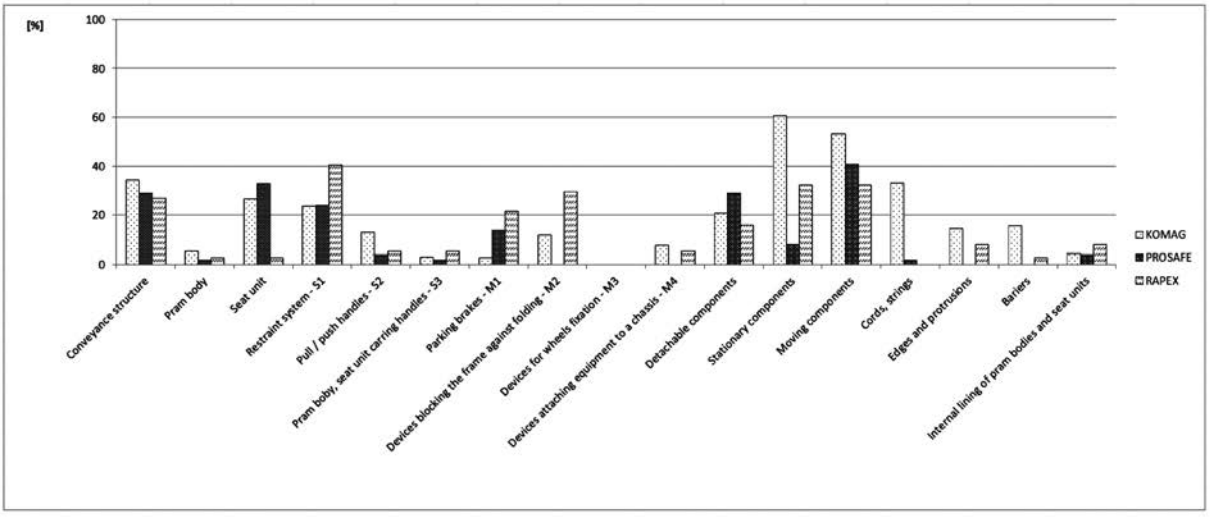

Fig. 4. Percentage share of components and equipment of the conveyances from Groups A, B, C1, and C2 that do not meet safety criteria

In 50% of tested strollers, there were dangerous holes and openings in stationary components, where a child could put in fingers or feet. The openings were found in the seat units of the strollers, including backrests and canopies attached to them, as well as between the stroller frames and the footrests. In 46% of tested wheeled child conveyances, gaps between moving parts, such as canopy and footrests stiffening, could lead to squeezing and shearing the child fingers. In the case of 50% of prams and strollers, too long cords or strings for folding canopies were used. Other cases of not meeting the safety criteria by the conveyances of Group B concerned the following components: push/pulling handle bars S2, devices blocking the frame against folding M2, seat units, edges and protruding parts, conveyances structures, restrained systems, and detachable parts.

When testing the durability of the push/pull handles, in 10% of the tested samples, the brakes, or the device blocking the frame against folding or the child restrained systems, were damaged. With respect to the devices blocking the frame against folding, 20% of the tested conveyances were not equipped with mechanisms operating automatically, and in 10% of them, the device was damaged during the durability test. In the case of 20% of conveyances from Group B, the angle between the seat unit and the backrest was too small. During fatigue tests, the rear wheel of the wheeled child conveyance was detached or the tire was damaged in 7.5% of strollers. The canopy rods in 17% of the tested conveyances had sharp edges. In 8% of Group B conveyances, during testing the strength of fasteners, they were released, and in 8% of the conveyances after applying the force of 90 N, the labels on the canopy, leg covers, mosquito nets, and shoulder strap adjusters being small parts, were detached.

The conveyances combining pram and stroller function (Group C1) did not meet the criteria for stationary and moving parts, conveyance structures, seat units, restrained systems S1, detachable elements, and barriers. In 69% of Group C1, conveyances, dangerous openings and gaps appeared, where the child's fingers, feet, or head could be entrapped. They were found at pram body bottoms, seat units, backrests, barriers, and between the frames and seat units and footrests, as well as between push/pull handles and pram bodies. In 50% of tested conveyances, the gaps between moving parts, including the canopy rods, seats, backrests and footrests, the risk of squeezing and shearing the child fingers was found. During the fatigue tests, in 9% of the tested conveyances, the pram body's plywood broke. In 18%, the front wheel was detached, and, in 9%, the mudguards detached and the rear wheel shock absorbers were damaged. The structures of 11% of the conveyances from Group C1 were instable. During the dynamic strength tests, in 20% of the conveyances, the buckle and the regulator of the child's crotch and shoulder fastening system were damaged. With regard to seat units, in 23% of Group C1 conveyances, the angle between the backrest and the seat unit was too small, and, in 8% of them, it was too large. In 14% of combined conveyances, an ineffective child restrained system was used. During the tensile tests, in 22% of the tested conveyances, separation of the rubber band, fasteners, and strings from the sliders occurred, and, in 13% of them, the barrier filling material was released and could be swallowed by a child.

In the case of wheeled child conveyances, equipped with a pram body, seat units, and car seats (Group C2), the criteria were not met by the following components: moving and stationary components, cords and strings, conveyance structures, child restraint systems S1, detachable parts, seat units, edges and protruding parts, push/pull handles S2, pram bodies, the lining of pram bodies and seat units, parking brakes M1, attaching devices for the chassis M4, carrying handles for pram bodies, and seat units S3.

In 63% conveyances of Group C2, gaps between moving parts, which can pose a potential shear and compression hazard for fingers, were found. They were identified between canopy rods and seat units, frames and footrests, canopy tubes and barriers, seat units and backrests, backrests and the bottoms of pram bodies, and parts of the seat unit restraint systems and their housings. Openings and gaps that could cause fingers entrapment were found in 61% of tested conveyances in pram body bottoms, barriers, seat units, and backrests, handles and attachments of their fastening systems, as well as between frames and seat units, canopies and footrests, push/pull handles and pram bodies, feet or head. Straps at mattresses and cords at seat units and canopies in 44% of the three-functional conveyances were too long. Thirty four percent of the conveyances were damaged during fatigue and dynamic strength tests: In 8%, the chassis connection was broken or the pram body was torn from the chassis fixation, and, in 4%, the front wheel was detached, or the tube or the seat unit's plate were broken, and the pram body was separated from the chassis, or the fenders were detached and the shock absorbers at rear wheels were damaged. Eight percent of Group C2 conveyances show instability, and in four percent, an excessively large angle of inclination towards the head or legs was found. Fastening systems in 32% of tested conveyances were ineffective or were damaged or were released during strength tests. In 29% of Group C2 conveyances, the fastener adjusting systems, elastic bands, zippers, and upholstery snap fasteners were separated during the tensile tests, and 22% of them had dangerous filling of barriers that could be swallowed by a child. The angle between the backrest and the seat, in 14.5% of the tested conveyances, was either too small or too large. In 21% of Group C2 conveyances, sharp edges were identified in the child fastening systems and on pipes and bolts that connect them. During the durability tests of push/pull handle bars, devices preventing the frame against folding as well as bolted connections of the frame were damaged in 10% of the tested conveyances. Pram bodies in 8% of conveyances had too low or sagging sidewalls. However, 5% conveyances of Group C2 were equipped with ineffective parking brakes. During the durability tests, the devices fixing the equipment on the chassis were damaged in 4% of the tested conveyances. Anchorage points for the carrying handles in 4% of pram bodies were placed too low, and the lining in 8% of pram bodies was not stretched sufficiently.

At Stage 6, the results of this research work, were compared with the results of PROSAFE Joint Action JA2011 [27] project and with RAPEX notifications [28] – Fig. 5.

The comparative analysis showed that the samples of wheeled child conveyances tested by the authors, similarly as in the PROSAFE project, did not meet the requirements of EN 1888 Standard [22]. The hazards related to their use were mainly associated with the following: dangerous gaps between moving or detachable components, small parts, incorrect angles between the backrest and the seat, a weak or unstable conveyance structure, and ineffective fastening systems.

The results of the research project realized by the authors indicated the following:

– There was a greater share of conveyances with dangerous holes and gaps in fixed components or too long cords and strings in the total number of tested samples than in the PROSAFE project.
– There was a smaller share of conveyances with ineffective brakes than in the PROSAFE project.

A comparison of the results of both projects showed that the hazards were also related to the following: improperly stretched interior linings of the pram body

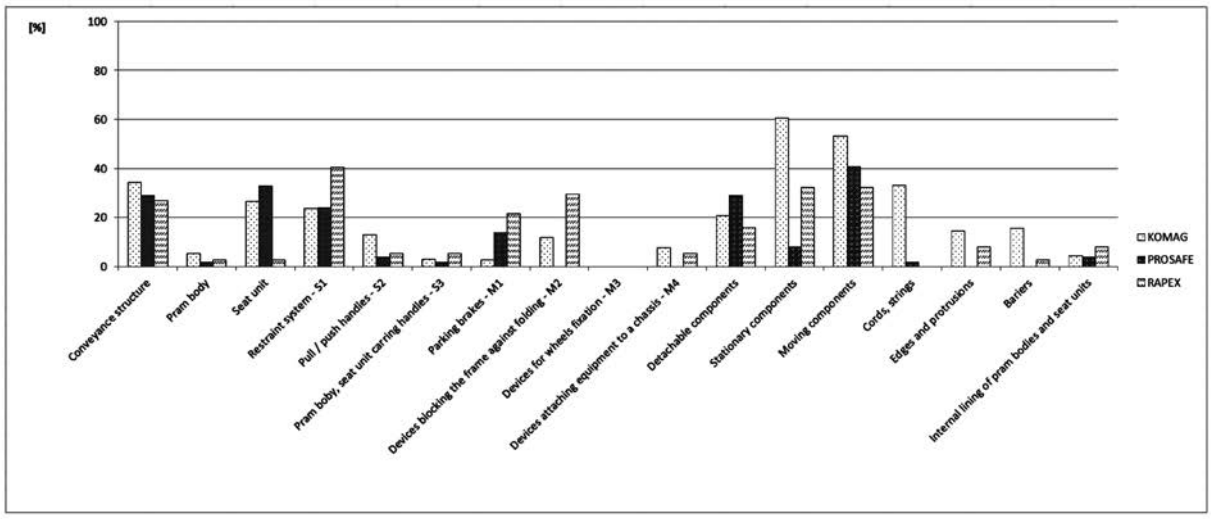

Fig. 5. Percentage share of the conveyance components and equipment which do not meet safety criteria, basing on the tests conducted by KOMAG Institute as well as on test results of PROSAFE project and RAPEX notification
Source: modified by the authors, based on [27–29].

Table 5. Subassemblies, mechanisms, components and equipment of the conveyances from A, B, C1, and C2, which require improvement in their structure

Conveyances group	Subassemblies, mechanisms, components and equipment of the conveyances, which require improvement in their structure
A	connections of frame and wheels with a chassis
	attachment devices for pram bodies
	device blocking the frame against folding
	openings in pram bodies bottom
B	openings in seat units and backrests
	gaps between footrests or hoods and frames
	cords and strings for folding the canopy
	handles for pulling / pushing the conveyances
	device blocking the frame against folding
	adjustment of backrest position
	finishing of conveyance frames
	connections of wheels with a chassis
C1	openings in: pram bodies bottom, seat units, backrests, barriers, canopies
	gaps between footrests and a frame as well as, between pram bodies and pull / push handles
	connections of wheels, shock absorbers, fenders with the chassis
	stiffening of pram body bottoms
	device adjusting the backrest position
	fixation of rubber bands and zippers in seat units, canopies and covers
C2	openings in: pram bodies bottom, seat units, backrests, canopies
	gaps between footrests and a frame
	cords and strings for folding the canopy, in seat units and in pram bodies
	connections of wheels, shock absorbers, fenders, baskets with a chassis
	devices fixing pram bodies on a chassis
	stiffening of seat units
	fastening systems
	device adjusting the backrest position
	fixation of fastening system components, rubber bands, zippers in seat units, canopies and covers
	barrier covers
	finishing of a conveyance frame
	height of side walls in pram bodies
	lining in pram bodies

and seats, too low sidewalls of the pram body, weak or not durable devices preventing the frame against folding, or devices fixing equipment on the chassis, and sharp edges and protruding parts, in less than in 5% of the tested conveyances. The lack of conveyances not meeting the criteria of devices for wheel fixation (M3) indicated the durability and strength of these devices.

The above was also confirmed by notifications of wheeled child conveyances to the RAPEX system [28]. Of the 38 conveyances notified to the RAPEX system, in the period from 2012 to the end of the first quarter of 2018, 41% did not meet the requirements for fastening systems, 32% for moving and non-moving components, 30% for frame locking devices, 27% for structures, 22% for brakes, and 16% for detachable components.

In case of the seat unit criteria, on the grounds of difference between the KOMAG and PROSAFE results and the RAPEX notification, it was concluded that unit parameters were randomly assessed by the surveillance authorities.

No cases of not meeting the safety requirements for wheels fixing devices and for strings and cords of the conveyances were reported. For other components, the number of conveyances that did not meet the requirements did not exceed 10% [28].

At Stage 7, based on the above comparisons, the subassemblies, mechanisms and components of the conveyances from Groups A, B, C1, and C2 that require improvements at their designing and manufacture stages are listed in Table 5. The cases, when failure to meet the safety criteria accepted by the authors was reported only once or was doubtful, were neglected.

Analysis of the conveyance components showed that the structure of pram bodies and seat units as well as their connection with a frame requires improvement in all conveyance groups regarding the elimination of dangerous openings and gaps in moving and stationary components, being within a child protected volume SD1–SD4, in which the child's fingers, head, or limbs could be entrapped and further squeezed, crushed, or cut off.

Wheel connections with the chassis are also important components that require modification. Implementation of the design solutions increasing the strength of their fixation is indispensable.

Conclusions

Designs of wheeled child conveyances are in constant development to adapt them to changing lifestyles, including increased mobility of people, advancements in technology, changing fashion, and first of all to increase a child's comfort and safety. Changes in the conveyances design are focused on the improvement of their functionality, especially their folding, transportation, and storage [31], as well as the reduction of their weight by using state-of-the-art materials, e.g., polycarbonic materials for their manufacture [32].

Despite changes in the conveyances design, the conveyances posing a hazard to children are still available on the market.

Results of the project realized by the authors, the PROSAFE project, and notifications for the RAPEX system showed that hazards presented by the conveyances are especially induced by structures that are not durable or instable, inefficient fastening devices, improper angles between backrest and a seat unit, dangerous openings and gaps in moving and stationary components, and by detachable and small parts in a child protected volume. The mentioned mechanisms and subassemblies require further studies on their modernization.

Suggested changes, presented in the new draft EN 1888-1 standard, support a presumption that safety of using the wheeled child conveyances will be improving due to including more detailed methods for testing the conveyances stability and testing cords and strings. In the new standards, it is planned to have to more stringent requirements aiming at the elimination of dangerous openings and gaps, especially scissors-like ones, which will additionally improve the safety of these conveyances [33].

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