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Normal ranges for proprioceptive tasks in 6-year-old children in Mangaung

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Background: A well-developed proprioceptive system is essential for motor control, muscle tone and voluntary movements. Sound proprioceptive development of young children can positively influence their motor abilities, while adequate movement abilities consequently form a strong foundation for young children entering the formal school setting.

Aim: This study aimed to establish normal ranges for proprioceptive tasks in 6-year-old children.

Setting: This study was conducted in the Mangaung, Motheo district, including 10 schools from five different quintiles.

Methods: One hundred and ninety-three, 6-year-old participants (mean: 6.46, SD 0.27 years) were included in the study, of which 97 (50.3%) were boys and 96 (49.7%) were girls. Five field-appropriate tasks were identified to establish participants' proprioceptive abilities. Statistical analysis was largely descriptive of nature, and normal ranges were established based on the interquintile range of each task, which represented the middle 50% of data (between the 25th and 75th percentiles).

Results: Normal ranges were identified as follows: 6–10 successful repetitions for the Angels-in-the-snow task; 22–30 s for the Rhomberg task; two to three successful repetitions per arm for the finger-to-nose task; two to four successful repetitions for the shoulder-level-arm raise (both arms and preferred arm), one to four successful repetitions for the shoulder-level-arm raise (non-preferred arm) and correct identification during the force perception task.

Conclusion: Most tasks had a ceiling effect, and thus it is necessary for practitioners to use these established normal ranges of proprioceptive tasks for 6-year-olds to identify children with proprioceptive difficulties.

Contribution: Proprioceptive difficulties of 6-year-olds can be identified using the normal ranges established.

Keywords: proprioceptive system; development, norms; Angels-in-the-snow; Rhomberg; finger-to-nose; shoulder-level-arm-raise; force perception.

Introduction

Children are regularly exposed to changing surroundings where they learn how to handle interactions with the environment by collecting information from their senses (Goodway, Ozmun & Gallahue 2019; Tarakci & Tarakci 2016). This interaction includes information received from sight, touch, hearing, smell, as well as the vestibular and proprioceptive senses (Tarakci & Tarakci 2016). Different sensory experiences are crucial to children's motor development, as sensory information help them to learn how to coordinate large and small muscles (Tahir et al. 2019). Motor development during early childhood is exceptionally important as it forms the basis for other developmental domains such as academic skills used by children later in their lives (D'Hondt et al. 2010). A mature proprioceptive system is thus not only essential for effective motor control, muscle tone and voluntary movement execution (Holst-Wolf, Yeh & Konczak 2016) but also for academic success (Balakrishnan & Rao 2007).

Proprioception is defined as the perception of joint and body movement, as well as position of the body or segments of the body in space (Han et al. 2016). Research argues that proprioception and kinesthesia are synonymous (Han et al. 2016), while recent reported findings highlight the involvement of both sensory and motor aspects when referring to kinesthesia (Jameel, Yasmeen & Jokerst 2019). Proprioception and kinesthesia thus play a role in integrating body systems to arrange the action of muscles, joints and limbs to acquire strength, speed and resistance in order to perform an intended motor task (Dos-Santos et al. 2014). For the purpose of this article, the term *proprioception* will encompass utilisation of both proprioceptive activation and kinesthetic sense.

Valori et al. (2020) report that children below the age of eight make significant movement errors because of an immature proprioceptive system, while Peterson, Christou and Rosengren (2006) state that the stabilisation of sensory systems such as the proprioceptive system can be expected at 12 years of age. The importance of intact proprioception for the successful execution of motor functions is highlighted by Woo et al. (2015). It is also reported that children use their vestibular and proprioceptive systems in order to develop a sense of balance and body position, which aids them in movement and positioning themselves in space (Tahir et al. 2019; Tarakci & Tarakci 2016). In South Africa, Pienaar, Van Reenen and Weber (2016) report only partially mastered fundamental movement skills in a group of 6-year-old children. A possible reason stated by these researchers for non-mastery of fundamental movement skills is that 6-year-olds depend more on other sensory systems such as the visual system, instead of fully relying on their proprioceptive system when executing complex body coordination skills (Pienaar et al. 2016). As young children's proprioceptive systems are still developing, and proprioception is seen as a foundational aspect to movement skills, research evaluating the proprioceptive abilities of children is necessitated, with several researchers (Peterson et al. 2006; Tahir et al. 2019; Tarakci & Tarakci 2016; Valori et al. 2020) supporting the need for children's proprioception to be assessed.

Unfortunately, a limited number of available standardised and norm-referenced assessments of proprioception exists for use in the paediatric field (Chu 2017). Although different types of assessments are available to measure proprioception, no set measure is advised by researchers (Hillier, Immink & Thewlis 2015). Indirect measures used to assess proprioception in children include the sensory profile, sensory processing measure and sensory integration and praxis tests (Chu 2017). Other measures to assess proprioception involve extensive laboratory equipment that are not accessible and feasible to most practitioners (Chu 2017). In the South African context, movement specialists are not always able to access costly equipment, and most parents in low- to middle-income households (Statistics South Africa 2021) are not able to pay a vast amount of money for their child to be assessed.

At 6 years of age, children in South Africa enter the formal school setting as grade one learners (South African Government 2023). By this time, they need to have the necessary developmental building blocks in place to ensure a strong foundation for future movement success and academic requirements (Pienaar et al. 2016; Van Zyl 2011). A well-developed proprioceptive system at 6-years will aid young children to move sufficiently and set them up for future academic success (Cameron et al. 2016; Peterson et al. 2006; Valori et al. 2020). With the importance of sound proprioception in mind, together with limited South-African context-appropriate proprioceptive assessments available, this study aimed to establish normal ranges for proprioceptive tasks of 6-year-old children in the Mangaung, Motheo district, South Africa.

Methods

Study design

This study was conducted using a quantitative cross-sectional design with a descriptive and analytical approach.

Context of the study

Schools in South Africa are ranked based on a quintile system (one to five). Schools in low-income areas are ranked as quintile one and two; middle-income area schools are classified as quintile three and schools situated in affluent areas are ranked as quintile four or five (Mestry 2014:859). Quintiles one to three schools are no-fee schools, which means they receive all their funding from the government, including finances for stationery, textbooks, electricity, water and sanitation, as well as repairs and maintenance (Maistry & Africa 2020). It is said that the lower quintile schools are not allowed to charge school fees, whereas quintile four and five schools charge fees (Maistry & Africa 2020:2). The ratio of different quintile schools involved during the planning of the current study was substantiated by the purpose to collect data, which would to an extent be a good representative of the South African population in the Manguang, Motheo district.

Sampling

Six-year-old children from a convenient sample of 10 schools spanning all five quintiles in the Mangaung, Motheo district, were included in this study. One quintile one, one quintile two, four quintile three, three quintile four and one quintile five schools participated in the study. The inclusion criteria allowed for inclusion of 6-year-olds from the identified schools, but only if principal and parent consent, as well as child assent, were obtained. Children with physical and/or mental disabilities, ear infection or known vestibular problems as well as children absent on the day of testing, as indicated by the teacher, were excluded. Consent was received for 222, 6-year-old boys and girls, and after inclusion and exclusion criteria were applied, 193 participants were included in the study.

Ethical considerations

This study was approved by the Health Sciences Research Ethics Committee (HSREC) of the University of the Free State (UFS) (UFS-HSD2020/0143/210) as well as the Department of Basic Education (DoBE). All aspects of data collection were conducted according to the ethical guidelines and principles of the South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research. Consent was obtained from the principals of each school to collect data at the identified school. Consent was also obtained from the parents and/or guardians of the recruited children and assent from the participants was obtained prior to the commencement of data collection. A participant number, instead of a participant's name, was used to ensure privacy, and all data were handled confidentially and according to the above-mentioned guidelines. Measurement errors were reduced as far as possible by ensuring adequate training of the field workers and the interpreter, as well as proper demonstration and explanation of the tasks to participants. Optimal testing time (length and time of day) was allocated when data were collected, and handling of raw data was quality controlled.

Procedure

Pilot study

After obtaining ethical clearance, a pilot study was conducted. The pilot study included two participants at each of the identified schools to determine a favourable testing environment, the need for trained interpreters and test form suitability. All of the afore-mentioned aspects were in order during the pilot study; hence, the data were included in the results of the main study.

Field worker and interpreter training

Before commencement of the main study, field workers were trained with a theoretical session (in-class) for an hour where the theory of proprioception was discussed as well as the proprioceptive tasks were elaborately explained. Field workers then also had an hour practical session where they were teamed up and had to perform the tasks and take turns to score the other. All training was done by the main researcher. Fourteen field workers were used to collect data; however, only three to four field workers were used at each school per data collection session. The interpreter also followed the same training as the field workers.

Data collection

Forty consent forms were handed out to each of the relevant grade one classes at each identified school. Data collection commenced after all needed consent and assent was obtained. Data were collected using the proprioceptive tasks as described in detail under the measurement instruments section. Testing of proprioceptive abilities was done by the researchers and pre-trained field workers, while the assistance of the pre-trained interpreter was available during all data collection sessions. Participants were tested individually. Testing commenced in the morning at a time that was suitable for each school and at a time that did not intrude on formal academic instruction time and continued for one and a half to 2 h per each school's grade one group. Formal administration of the tasks took approximately 10–15 min per participant but did depend on the degree of difficulty experienced by the participant. The tasks were performed in a randomised sequence in order to reduce the possible occurrence of fatigue and to prevent participants being able to communicate the order of the tasks to their peers.

Measurement instruments

Five tasks were identified to measure the proprioceptive abilities of participants (Cheatum & Hammond 2000; Chu 2017). Tasks such as the Angels-in-the-snow, Rhomberg and finger-to-nose were identified as they have generally been used by other researchers to determine proprioceptive abilities in terms of motor control, motor coordination and kinesthesia (Moran et al. 2005; Swaine et al. 2005). The other two tasks (Shoulder-level arm-raise and Force perception) have also been indicated by researchers (Cheatum & Hammond 2000; Chu 2017) as measurements of proprioception or aspects thereof. Unfortunately, the identified tasks have no specific reported validity or reliability values (Cheatum & Hammond 2000; Chu 2017), but they do, however, have set execution instructions that were strictly followed. Currently, no cut-off values or norms for South African children are available for the five identified tasks.

The test form for each participant included a sequence number; participant's gender, height, weight, hand dominance (determined by notating the hand they used to sign the assent form), birth date, chronological age, as well as a table to record raw scores. Quantitative data were recorded specific to each task, as explained below at each of the five proprioceptive tasks. Qualitative data were recorded as a 'yes' or a 'no' based on the qualitative criteria of each task, whereafter it was quantified for data analysis purposes.

Guidelines for the execution of the kinesthetic coordination tasks included:

Angels-in-the-snow: Researchers have used the Angels-in-the-snow task in order to evaluate children's coordination (Mutti et al. 2017). Before commencement of this task, the researchers taped a solid vertical straight line on a yoga mat for the participant to lie on, with the line being in the middle of their bodies. Researchers then told the participant that they will point to limb/s that need to be moved, that they should not lift it up and that they need to return it to normal relaxed position. Participants needed to perform a series of 11 consecutive movements as derived from Cheatum and Hammond (2000), and they had to execute at least four consecutive correct repetitions per movement to be successful. Execution was scored as a number out of 11. Eleven represented the 11 movements of the Angels-in-the-snow task. Points were scored as a 1 or 0. Scoring a 1 indicated that participants correctly performed a movement for four consecutive repetitions. Participants that could not correctly perform the movement for four consecutive repetitions received a 0. The total amount was then added to get a number out of 11. The qualitative movement aspects that were recorded included the occurrence of associated movements; moving other parts of the body together with limbs, uncoordinated movements, movement hesitation, looking at limbs and touching or banging limbs against the floor to 'wake them up'. Qualitative movement aspects were scored as a yes or no on the test form.

Rhomberg: This task evaluated balance in a standing position. Participants stood with feet together; their arms relaxed at their side. The researcher asked the participant to stand up straight and keep balance with their eyes closed. Data were recorded as the number of seconds the participant was able to stand in the specified position. A maximum of 30 s could be recorded. If the participant is able to hold balance for 30 s, the balance task is considered a good indicator for balance (Madureira et al. 2007), and therefore the cap of 30 s was used and deemed valid. Qualitative movements aspects referred to weaving and/or swaying of body or limbs or moving and/or lifting limbs (Cheatum & Hammond 2000).

Finger-to-nose: Different versions of the finger-to-nose task exist (Cheatum and Hammond 2000; Sayar & Űnűbol 2017; Swaine et al. 2005). For the purpose of this study, the finger-to-nose task was done by extending both arms next to the body to shoulder level and then with each index finger alternating touching the tip of the nose and returning the arm to original position, while eyes are open and then closed. The required number of successful repetitions performed by the participant was three touches of each index finger to the nose, which equals a maximum amount of six. The qualitative movement aspects provided specific information regarding unusually fast or slow movements, if the hand moved consistently to the right, left, top or bottom and if the participant missed the nose by 1 cm–2.5 cm.

Shoulder-level arm-raise: This task was used as set out by Cheatum and Hammond (2000) and assessed the movement of a limb around a joint and in space. Participants stood with eyes closed and then raised arm and/or arms to the front in the following ways: raising preferred arm to shoulder level and then non-preferred arm and then both arms. Data were recorded as a number of correct repetitions performed up to a maximum of four for each of the required movements. The qualitative movement aspects recorded, observed wrist drop, arm and/or arms level and body position or correct body posture.

Force perception: This task, as set out and explained by Chu (2017), was used to assess force sense. The participants stood with arms stretched out in-front of them with eyes closed. A light weighted object (500 g) was placed in one hand, and a heavier weighted object (1 kg) was placed in the other hand. Ankle and/or arm weights (same length, different sizes) were used for this task. The participant needed to tell the researcher that hand had the heavier weight in. This task was performed only once, where a score of 1 was given if the heavier weight was correctly identified and a 0 if identification of the heavier weight was incorrect. The qualitative movement aspects observed swaying and/or movement of the body.

Data analysis

Collected data were entered into a Microsoft Excel spreadsheet, converted into a SAS data set and analysed by a biostatistician using the SAS software (SAS Institute Inc. 2017). The statistical analysis of the data was largely descriptive. Quantitative variables were summarised using descriptive statistics (mean, SD, minimum, percentile (P) 25, median, P75, maximum). For quantitative proprioceptive measurements, the following additional percentiles were calculated to estimate normal ranges for each of the variables: P5, P10, P90 and P95. Categorical variables were summarised using frequencies and percentages for variables indicating quality of movement or correctness in carrying out a task. Normal ranges for 6-year-old children were established based on the interquintile range (25th and 75th percentiles) of each variable, representing the middle 50% of data.

Results

Participants (N = 193) with an average age of 6.46 years (SD, 0.27), of which 97 were boys (50.26%) and 96 were girls (49.74%) participated in the study. The participant group had an average weight of 21.9 kg (SD, 8.72) and an average height of 117.17 cm (SD, 7.44), with 20 (10.36%) being left handed and 173 (89.64%) being right handed.

Table 1 presents descriptive statistics and normal ranges for proprioceptive tasks as established from 193 six-year-old participants in the Mangaung, Motheo district. The interquintile range represents the execution of proprioceptive tasks between the 25th and 75th percentiles. This middle 50% of data was defined the expected norm for children of this age, with specific emphasis on the 25th percentile and lower as identifiers of proprioceptive difficulties. Lower ranges are especially importance in this study, as they can be used to identify children with proprioceptive difficulties.

For Angels-in-the-snow, the normal range is 6–10 successful executions of the 11 movements for this task. The normal range established for the Rhomberg task is set at 22–30 s. Two to three repetitions (reps) for the left and right hand are identified as being the normal range for the finger-to-nose task. The shoulder-level-arm raise task makes use of the preferred arm, non-preferred arm and both arms. For the preferred arm, the normal range is set as two to four successful reps. With regard to the non-preferred arm, the normal range is one to four successful reps. For the last movement (both arms), the normal range is considered as two to four successful reps.

TABLE 1: Descriptive statistics and normal ranges for kinesthetic coordination tasks (N = 193), excluding force perception.

Variable	Angels-in-the-snow	Rhomberg	Finger-to-nose		Shoulder-level-arm raise		
			Left	Right	PA	NA	B
Mean	7.66	25.52	2.34	2.48	2.9	2.65	2.88
SD	2.87	7.63	1.07	0.96	1.57	1.64	1.57
Min	0	0	0	0	0	0	0
P5	2	8	0	0	0	0	0
P10	4	12	0	1	0	0	0
P25	6	22	2	2	2	1	2
P50	8	30	3	3	4	4	4
P75	10	30	3	3	4	4	4
P90	11	30	3	3	4	4	4
Max	11	30	3	3	4	4	4

B, both; Min, minimum; Max, maximum; NA, non-preferred arm; P, percentile; PA, preferred arm; SD, standard deviation.

Table 2 summarises the number of successful repetitions of each of the 11 movements of the Angels-in-the-snow task. The participants found it relatively easy to execute movement tasks one to seven, while the number of successful executions visibly decreased from tasks 8–11. Only 60% of the participants were able to execute four successful movements with the right arm and the right leg simultaneously (movement 8), while 59% were successful in moving the left arm and the left leg simultaneously (movement 9). This percentage decreases even further for movement task 10 and 11, with only 36% successfully moving the right arm and left leg simultaneously for four repetitions and only 28% being able to do four successful movements with the left arm and right leg simultaneously.

Table 3 focuses on the qualitative movement aspects of the Angels-in-the-snow task. Most participants did not struggle with uncoordinated movements or with touching or banging their limb and/or limbs. More than 60% of participants, however, performed the movements with hesitation, while almost half of the participants did look at their limb and/or limbs.

Table 3 to Table 7 report on the movement quality of each of the proprioceptive tasks.

Table 4 indicates that almost half the participants did lose their balance, moved their feet and lifted their arm and/or arms while executing the Rhomberg balance task. The majority of participants (70.47%) did not weave back and forth during execution of the task.

TABLE 2: Qualitative statistics for the 11 Angels-in-the-snow movements.

Movement	Statistic	Successful repetitions				
		0	1	2	3	4
1	Freq	15	7	14	26	131
	%	7.77	3.63	7.25	13.47	67.88
2	Freq	10	3	11	9	160
	%	5.18	1.55	5.70	4.66	82.90
3	Freq	6	2	0	6	179
	%	3.11	1.04	0.00	3.11	92.75
4	Freq	12	6	3	18	154
	%	6.22	3.11	1.55	9.33	79.79
5	Freq	12	8	4	11	158
	%	6.22	4.15	2.07	5.70	81.87
6	Freq	13	2	3	8	167
	%	6.74	1.04	1.55	4.15	86.53
7	Freq	13	2	2	2	174
	%	6.74	1.04	1.04	1.04	90.16
8	Freq	28	6	13	30	116
	%	14.51	3.11	6.74	15.54	60.10
9	Freq	27	14	12	26	114
	%	13.99	7.25	6.22	13.47	59.07
10	Freq	55	19	19	30	70
	%	28.50	9.84	9.84	15.54	36.27
11	Freq	71	22	20	25	55
	%	36.79	11.40	10.36	12.95	28.50

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

Table 5 suggests that participants did not struggle with the finger-to-nose movement task, except for missing the nose (30.57%) and missing the tip of the nose by more than 1 cm (41.45%).

In Table 6, it is evident that most of the participants did not have difficulty lifting the preferred arm, non-preferred arm and both arms to shoulder level. Participants did, however, have difficulty lifting arms to the same level during each repetition, as half of them (50.26%) could not successfully do this.

Table 7 summarises the force perception task. Most participants could perform this movement task correctly and did not have a lot of difficulty identifying the heavier object. Furthermore, more than 90% of participants did not sway or bend their body in any direction.

Findings

This study aimed to establish normal ranges for five identified proprioceptive tasks in 6-year-olds from the Mangaung, Motheo district in South Africa. Our findings show that the five proprioceptive tasks can be useful in identifying 6-year-old children with proprioceptive

TABLE 3: Quality of movements for Angels-in-the-snow.

Associated movements		Uncoordinated		Hesitation		Looks at limb and/or limbs		Touches and/or bangs limbs	
Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
20	10.36	65	33.68	116	60.10	84	43.52	37	19.17

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

TABLE 4: Quality of movement for Rhomberg task.

Balance loss		Weaving		Moves feet		Lifts arms	
Freq	%	Freq	%	Freq	%	Freq	%
94	48.70	57	29.53	78	40.41	84	43.52

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

TABLE 5: Quality of movement for finger-to-nose task.

Fast and/or slow		Right and/or left		Top and/or bottom		Misses nose		Misses tip		Random and/ or unsteady	
Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
20	10.36	40	20.73	45	23.32	59	30.57	80	41.45	30	15.54

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

TABLE 6: Quality of movement for shoulder-level-arm-raise task.

Wrist drop		Not same level		Incorrect position		Sways and/or bends	
Freq	%	Freq	%	Freq	%	Freq	%
10	5.18	97	50.26	39	20.21	47	24.35

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

TABLE 7: Descriptive and qualitative data for the force perception task.

Correct hand identified		Sways and/or moves body	
Freq	%	Freq	%
161	83.42	17	8.81

Freq, frequency; %, percentage.
Please refer to measurement instruments for detailed information on qualitative aspects.

difficulties. The upper range (75th percentile) of the established normal ranges indicates that the tasks might been easy for competent 6-year-olds. It is highly recommended that the lower range (25th percentile) be used to identify children with proprioceptive difficulties or backlogs in proprioceptive development.

The findings of this study show that 6-year-old children should be able to do at least six out of the 11 movements of the Angels-in-the-snow task, as less than six successful executions indicate a possible proprioceptive difficulty. The findings of the current study also indicate that when 6-year-old children execute the Angels-in-the-snow tasks, they especially struggle with movements that rely more on body coordination, using their limbs bilaterally and contra-laterally, as well as movements that require greater muscle control. Explaining the second part of our finding, Karambe, Dhote and Palekar (2017) stated that bilateral coordination ability improves with age, as observed from a group of 5- to 15-year-old participants. Also, in agreement with our findings, Cheatum and Hammond (2000) stated that children aged 5–9, struggled with contralateral movements. Further underpinning findings from the current study, these researchers also report that movements develop in sequences, first with unilateral movements, then with homolateral movements (Cheatum & Hammond 2000). This is followed by bilateral movement coordination (Gazbare et al. 2020) and finally contralateral movements (Kakebeeke et al. 2017). Research on 3- to 12-year-old children indicated that motor skills that require more body coordination will require additional movement coordination abilities (Gandotra et al. 2021). The importance of implementing body and/or motor coordination programmes for children aged six and above in order to establish motor coordination skills needed in adulthood is thus highlighted (Lima et al. 2017). In contrast to our findings, Cheatum and Hammond (2000) reported specifically on the Angels-in-the-snow task and stated that children aged 5–9 years struggle with unilateral movements, which was not the case in our study.

For the Rhomberg task, it can be expected of 6-year-old children to keep static balance with eyes closed for at least 22–30 s. Not being able to stand with eyes closed for at least 22 s identify proprioceptive difficulty in 6-year-old children. The findings of this study also highlighted that 6-year-old participants have relatively stable stationary balance skill, but almost half of the participants could qualitatively not perform the Rhomberg task without loss of balance. A study done by Jiang et al. (2018) evaluated the static and dynamic balance on three to 6-year-old children and reported balance skills to improve with age. Jiang and co-workers reported no significant differences in static balance between the three and 4-year-old group, whereas a significant difference was found between the static balance of the 5- and 6-year-old group when compared to the 3- and 4-year-old group. Reciprocating the fact that static balance was significantly better in 5- and 6-year-olds (Jiang et al. 2018). The study of Jiang et al. (2018) also stated that balance and proprioception are crucial to the general development of skills needed by children, and that the ages of three to six are critical in child development. These aged children therefore need ample opportunities (at school and at home by means of play) to successfully establish their balance and proprioceptive abilities (Jiang et al. 2018).

The finger-to-nose task uses both arms and is a good indicator to establish if 6-year-old children can coordinate their body movements, mainly referring to the application of proprioceptive information during a two-arm coordinated movement. From findings of the current study, children aged six should be able to perform this task with two to three successful repetitions per arm, where one repetition or less implies proprioceptive difficulties. Swaine et al. (2005) stated that during the execution of the different finger-to-nose task versions, touching the tip of the nose is the most difficult, which was also observed in the current study. Our findings reciprocated those of Swaine et al. (2005), as participants more frequently missed the tip of their nose, compared to any of the other qualitative criteria (stipulated in the methodology section). According to Bo (2019), missing the tip of the nose can possibly indicate proprioceptive system functioning problems. No current studies could be found focussing specifically on spatial awareness and proprioceptive abilities of the 6-year-old child, and our findings could therefore not be compared to exact similar studies.

Adequate proprioception is indicated in 6-year-olds if they can successfully perform the shoulder-level-arm raise task with their preferred arm for at least two repetitions, their non-preferred for one repetition and both arms for two repetitions. The only qualitative difficulty experienced by participants in this task was that they could not lift their arm to the same level each time, which could indicate muscle tone and muscle control difficulties. Future research on clinical assessments for muscle tone and muscle control in children aged 3–11, such as the shoulder-level-arm raise task, is advised (Goo, Tucker & Johnston 2018). The reason for this recommendation pertains to the fact that only certain muscle groups are activated during such activities, in this case mainly the shoulder girdle muscles, where findings can contribute to our knowledge regarding muscle tone needed for movement activities and sport skills later on (Goo et al. 2018). Goo et al. (2018) are also of the opinion that such activities can be used as an assessment of muscle tone in specifically 6-year-old children. The shoulder-level-arm-raise task can consequently be more feasible compared to costly apparatus in determining muscle tone and muscle control in children.

The last task was force perception, and adequate proprioceptive ability for the 6-year-old child is indicated when the hand with the heavier object can be correctly identified. Participants performed well in the force perception task and were mainly successful in the task. To our knowledge, no studies related to specifically force perception in the 6-year-old child and force perception as a proprioceptive ability have been conducted, and therefore no comparable findings can be discussed.

Conclusion

Normal ranges for the following five proprioceptive tasks have been established for 6-year-old children: Angels-in-the-snow, Rhomberg, finger-to-nose, shoulder level-arm raise and force perception. The lower end of these norms (25th percentile) can be useful in identifying proprioceptive difficulties in children of this age, within the South African context.

Limitations, contributions and recommendations

The main limitation of the study was the impact of coronavirus disease 2019 (COVID-19) on national regulations and consequently school operations. Learners attended school on a rotation basis, which led to a low response rate (55.5%) of returned consent forms on the day of testing because of learner absence. Another limitation included the ceiling effect, thus meaning that the upper ranges are not feasible to conclude the findings. This phenomenon should be studied in future research to include tasks that are more challenging for children.

Despite these limitations, the current study contributes to our existing knowledge on proprioception and proprioceptive testing of 6-year-old children in South Africa. The topic is of importance and necessary, especially in the South African context, as seen from existing literature. Our findings have practical implication, which can assist movement specialists to identify proprioceptive difficulties in 6-year-old children, while it also sets the path for further research on this topic.

We consequently recommend that movement specialists such as Kinderkineticists and Physiotherapists use the established normal ranges for the five identified proprioceptive tasks in order to identify proprioception difficulties in 6-year-old children. Use of the shoulder-level-arm-raise task to evaluate muscle tone and control in children is also recommended, as it is more cost effective than clinical apparatus. Findings can also aid practitioners to recommend movement programmes for the correction of specific proprioception difficulties. The planning and conduction of further research on this topic should consider a larger sample size, with children of different ages and in other provinces of South Africa. It is also recommended that the reliability and validity of the five proprioceptive tasks should be established within future research to further enhance the use thereof in identifying proprioceptive difficulties in young children.

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Competing interests

The authors have declared that no competing interest exists.

Authors' contributions

C.B. wrote and collected data for this article. E.V.D.M. wrote, edited, reviewed and assisted in collecting data for this article.

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Data availability

The data that support the findings of this study are available from the corresponding author, C.B., upon reasonable request.

Disclaimer

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