Title: The applicability of a short form of the KörperKoordinationsTest für Kinder for measuring motor competence in children aged 6-11 years.

Submission type: Original investigation

ABSTRACT:

This study aimed to determine if the KörperkoordinationsTest für Kinder (KTK) remained a valid assessment of motor competence following the removal of the hopping for height subtest (KTK3). Children (n = 2479) aged 6-11 years completed all KTK subtests (KTK4) and Motor Quotient sum scores (MQS) were determined for KTK3 and KTK4. Classifications were established as MQS below percentile 5 (P5), MQS between percentile 5-15 (P15), MQS between percentile 15-50 (P15-50), MQS between percentile 50-85 (P50-85), MQS between percentile 85-95 (P85) and MQS higher than percentile 95 (P95). Pearson's correlation (r = 0.97) and cross-tabs (Chi^2=6822.53, p<0.001; Kappa = 0.72) identified substantial agreement overall between KTK3 and KTK4. However, when classified into separate age and gender categories, poor agreement (<60%) was found in girls: P15 at 8-11 years and P85 at 6-7 years; and in boys: P5 and P15 at 6 years, P85 at 8 years and P15 at 10 years. Researchers should consider these findings when selecting which KTK protocol to use.

Keywords:

talent identification, pediatrics, health, sports

INTRODUCTION

Coordinating sequential movement patterns is essential in the execution of purposeful action and is central for the acquisition of fundamental motor skills such as balance, locomotion and object control. These fundamental motor skills rely on components of physical fitness and motor coordination and the assessment of such skills has been collectively defined within a single construct - motor competence (Barnett et al., 2016; Robinson et al., 2015; Rudd et al., 2016; Utesch et al., 2016). Adequate levels of motor competence are essential for the performance of every-day motor skills. Therefore, motor competence is commonly assessed to determine children at risk of developing poor motor competence, which may result in an inability to perform every day activities and participate in health-related physical activity or organized sport.

In order to accomplish the assessment of motor competence, a range of protocols have been developed, each consisting of a battery of various tests. Each of these tests may focus on locomotion, object control and/or balance and it is important for researchers to identify the appropriate procedures and tests within those protocols relative to the specific population being assessed and the current variables of interest i.e. the research question (Barnett et al., 2016; Rudd et al., 2016; Utesch et al., 2016). For example, Rudd et al. (2016) suggest that the Test of Gross Motor Development (TGMD-2) and KörperkoordinationsTest für Kinder (KTK) both measure discrete areas of gross motor competence i.e. TGMD-2 incorporates assessments of locomotion and object control, while KTK measures body coordination. It is suggested that the individual protocols are suitable to measure specific areas of motor competence whilst a variety of assessment protocols must be used if the entire construct of motor competence is to be adequately assessed.

In addition to determining the appropriate testing protocol to suit the current research question, researchers must also consider the duration required to administer the protocol, the target age group and the potential risk of injury posed by performing each of the tests within the protocol. Typically, the Motoriktest für vier-bis seschsjärige Kinder: MOT 4-6 has been used within educational settings (Kambas et al., 2012; Zimmer & Volkamer, 1987) whilst the Movement Assessment Battery for Children: M-ABC-2 has been adopted for clinical testing, (Hendersen, Sugden & Barnett, 2007; Schulz, Henderson, Sugden & Barnett, 2011). However, each protocol has inherent limitations. Specifically, the M-ABC-2 requires approximately 45-60 min per participant to administer, limiting its practicality when used in a setting that requires a number of children to be assessed at the same time. In comparison, the MOT 4-6 requires 15-20 min per participant but has been specifically developed to suit children aged between 4-6 yr. As such, researchers have also adopted alternative shortened protocols such as the Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2) short form which assesses 14 items (15-20 min) per participant in comparison to 53 items (45-60 mins) for the BOT-2 complete form (Bruininks & Bruininks, 2006; Fransen et al., 2014b). It is important to note that while each of the aforementioned protocols consists of different batteries of tests, the assessment of motor competence within each protocol also varies e.g. the TGMD-2 provides a qualitative, subjective assessment e.g. whether a skill component is present or not, whilst the KTK, M-ABC-2, BOT-2 and MOT 4-6 provide quantitative, objective assessment e.g. number of sideways jumps completed (Rudd et al., 2016). While each of the aforementioned assessment protocols are able to identify specific aspects of motor competence that require improvement in atypically developing children, there has been a shift in scientific research towards protocols that can additionally be used to identify proficient children within a sporting setting (Deprez, Fransen, Lenoir, Philippaerts &

Vaeyens, 2015; Opstoel & Pion et al., 2015; Pion et al., 2015; Vandendriessche et al., 2012; Vandorpe et al., 2011).

The assessment of motor competence is often applied within the general population to identify children who may benefit from additional training, however motor competence assessment within sports and talent identification is becoming increasingly prevalent. For example, many youth sporting programs are now utilizing tests of motor competence in order to understand a child's general ability to perform a range of different motor actions (Opstoel & Pion et al., 2015; Pion et al., 2015; Vandendriessche et al., 2012). Whilst initially developed to detect motor competence deficiencies, the KTK has been one of the most frequently implemented motor competence tests in sports settings. The KTK predominantly focuses on measures of global motor coordination and components of physical fitness i.e. body coordination (Rudd et al., 2016) and has therefore been adopted across a number of individual and team sports such as soccer (Deprez, 2015; Vendendriessche et al., 2012), volleyball (Pion et al., 2015) and figure skating (Mostaert, Deconinck, Pion & Lenoir, 2016). The KTK assesses body coordination via four subtests i.e. walking backwards (WB), jumping sideways (JS), moving sideways (MS), and hopping for height (HH) (Kiphard & Schilling, 1974, 2007). Scores attained in these subtests can be converted into motor quotients (MQ) allowing for a comparison with age- and gender-specific norms. Collectively, the KTK has been demonstrated to be a reliable and valid assessment of motor competence ($r = 0.97$), with the test-retest reliability of the specific subtests ranging from 0.86 to 0.96 (i.e. WB = 0.80, JS = 0.95, MS = 0.85 and HH = 0.96). Furthermore, the total scores were able to distinguish between typically and atypically developing children in 91% of occasions (Kiphard & Schilling, 1974, 2007).

Although the reliability and validity of the KTK is well established, a number of studies have recently adopted the use of a KTK3 protocol via removal of the HH component when examining large population samples (Deprez et al., 2015; Mostaert et al., 2016; Opstoel & Pion et al., 2015; Pion et al., 2015; Vandendriessche et al., 2012). This is likely due to the observation that the HH component requires the same approximate duration to complete (~10 minutes per participant) as the other three subtests combined. Thus, removal of HH might substantially increase the practicality of the KTK. However, it is important for researchers to consider the applicability of HH to the specific study and population prior to excluding the test from the protocol. Interestingly, HH has been excluded within figure skating (Mostaert et al., 2016) and Volleyball (Pion et al., 2015) research (both sports in which HH may be important) due to safety concerns. Specifically, risk of ankle injury was cited in both cases although no data has yet reported injury incidence resulting from HH within the KTK protocol. While no injuries have been reported within the literature, the HH component requires participants to hop as high as possible followed by landing and then hopping once more. This component is technically challenging and requires a participant to have highly coordinated neuromuscular motor patterns in order to successfully and safely complete the movement. Without prior knowledge of a participant's landing mechanics and associated muscular strength it could place less competent individuals at an increased risk of ankle or knee injury, although data concerning this observation has not been reported. As such, the potential of removing this subtest is appealing to many researchers and practitioners as it may provide a safer protocol and further improves the practicality of the KTK protocol. However, it is important to note that there are currently no investigations that have examined the impact of removing a subtest on the overall validity of the KTK protocol. Therefore, the aim of this study was to determine the validity of a shortened form of the KTK (KTK3 – excluding HH assessment) when compared to the standard KTK protocol (KTK4).

METHOD

Participants

A total of 2479 children between 6-11 years participated in this cross-sectional study (1300 boys and 1179 girls). Children were recruited from 26 primary schools for general education throughout [redacted] **(Highlighted in black to facilitate blind review process).** The relevant local Ethics Committee granted approval for this study and written informed consent was obtained from the children's parent(s) or guardian(s).

Procedures

Detailed methodology of the KTK motor competence testing battery has been explained elsewhere (Vandorpe et al., 2011), however, briefly this test consists of four subtests: 1) walking backwards on balance beams (three different widths), 2) moving sideways as quickly as possible using two boxes, 3) jumping sideways over a board as many times as possible in 15 s, and 4) hopping over an increasing stack of pillows (trials using each leg) (Kiphard & Schilling, 1974; 2007). All children completed the four subtests of the KTK (walking backwards, moving sideways, jumping sideways and hopping for height) according to the KTK test manual (Kiphard & Schilling, 1974, 2007). All assessments were taken by trained supervisors in an indoor facility.

Data Analysis

To prepare the data for analysis, an age and gender standardized MQ was derived from raw subtest scores using the normative data provided in the KTK-NL (Lenoir et al., 2014). These MQs were then summated to determine the MQ sum score for the KTK3 and KTK4. According to the most recent version of the KTK handbook (Kiphard & Schilling, 2007), this sum score should be used to derive a general MQ for the entire test battery. However, as these derivations are based on the KTK using four subtests rather than three, and the weightings of each subtest within the total MQ were not explained, only the sum scored was used for further analysis.

To assess the validity of the KTK3, two analyses were conducted on the total sample, the sample per age group, the sample per gender and the sample per age group and gender. First, a bivariate Pearson correlation was used to measure the relationship between the MQ sum score of KTK3 and KTK4. Next, participants were classified into the following groups: MQ sum score lower than percentile 5 (P5), MQ score between percentile 5 and 15 (P15), MQ sum score between percentile 15 and 50 (P15-50), MQ sum score between percentile 50 and 85 (P50-85), MQ sum score between percentile 85 and 95 (P85) and MQ sum score higher than percentile 95 (P95). To assess the agreement in classification between KTK3 and KTK4, cross-tabs between both values were used and Pearson Chi-Square (Chi^2) and Cohen's Kappa (k) values were calculated and interpreted according to the following cut-off scores. Kappa between 0.21 and 0.40 was interpreted to be fair; between 0.41 and 0.60 was moderate, between 0.61 and 0.80 was substantial and a Cohen's Kappa bigger than 0.81 was considered an almost perfect agreement (Landis & Koch, 1977). Significance levels were set at $p \leq 0.05$.

RESULTS

General sample

Pearson bivariate correlation revealed a strong (r = 0.97) correlation between KTK3 and KTK4 for all age groups (Table 1). Cross-tabs revealed substantial agreement between the classification using KTK3 and KTK4 over all age groups (Chi^2=6822.53, p<0.001; Kappa = 0.72). The weakest agreement between KTK3 and KTK4 was for P15, and for P85, where 66.8% and 68.4% respectively were classified in the same category by KTK3 as by KTK4 (Table 2).

INSERT TABLE 1 HERE

INSERT TABLE 2 HERE

Table 1: Pearson correlation coefficients between KTK3-KTK4 for each gender and age group.

	Boys		Girls		Total sample	
Age group	*n*	Pearson r KTK3-KTK4	*n*	Pearson r KTK3-KTK4	*n*	Pearson r KTK3-KTK4
6 years	135	0.96**	166	0.97**	301	0.96**
7 years	228	0.97**	195	0.97**	423	0.97**
8 years	250	0.98**	236	0.97**	486	0.97**
9 years	276	0.97**	280	0.98**	556	0.98**
10 years	214	0.97**	148	0.97**	362	0.97**
11 years	197	0.98**	154	0.98**	351	0.98**
Total	**1300**	**0.97****	**1179**	**0.97****	**2479**	**0.97****

Table 2: Classification agreement between KTK3 and KTK4 for each gender.

KTK 3		Boys KTK4						Girls KTK4						Total KTK4					
		<P5	P5-15	P15-50	P50-85	P85-95	>P95	<P5	P5-15	P15-50	P50-85	P85-95	>P95	<P5	P5-15	P15-50	P50-85	P85-95	>P95
<P5	*n*	56	15					46	12					102	27				
	%	83.6	11.3					79.3	20.7					81.6	11.1				
P5-15	*n*	11	93	32				12	70	37				23	163	69			
	%	16.4	69.9	7.2				20.7	63.1	8.6				18.4	66.8	27.1			
P15-50	*n*		25	372	63				29	349	47				54	721	110		
	%		18.8	83.2	13.6				26.1	80.8	11.7				22.1	82	12.7		
P50-85	*n*			43	380	24				46	331	31				89	711	55	
	%			9.6	82.1	19.2				10.6	82.3	25.4				10.1	82.2	22.3	
P85-95	*n*				20	92	10				24	77	10				44	169	20
	%				4.3	73.6	15.4				6	63.1	18.5				5.1	68.4	16.8
>P95	*n*					9	55					14	44					23	99
	%					7.2	84.6					11.5	81.6					9.3	83.2
Total	*n*	**67**	**133**	**447**	**463**	**125**	**65**	**58**	**111**	**432**	**402**	**122**	**54**	**125**	**244**	**879**	**865**	**247**	**119**

Note: % represents classification agreement of KTK3 within KTK4

Organised by age group

Associations between KTK3 and KTK4 were between (r = 0.96 – 0.98) for all age groups (Table 1). Classification agreement was substantial (Kappa = 0.69 – 0.75) for all age groups (Table 2) and generally increased with age (Table 3). At 6 years, the lowest classification agreement was found for P5, where only 57% of cases classified in this category were classified accordingly by KTK3 and for P85, with an agreement of 46.2%. At age 7, 8 and 9, classification agreements ranged from 60%-95% for all percentile groups. At 10 and 11 years, there is poor agreement between both measures for P15 where only 57.9 and 53.8% respectively were correctly classified by KTK3.

INSERT TABLE 3 HERE

Table 3: Categories with highest and lowest agreement between KTK3 and KTK4.

	Boys		Girls	
Age group	Highest agreement (%)	Lowest Agreement (%)	Highest agreement (%)	Lowest Agreement (%)
6 years	P50-P85 (87.0)	P5 (50.0), P85 (50.0)	P15-P50 (85.9)	P85 (45.0)
7 years	P95 (93.3)	P15 (73.9)	P95 (100.0)	P85 (52.0)
8 years	P15-P50 (88.2)	P85 (52.9)	P50-P85 (88.9)	P15 (58.8)
9 years	P5 (92.3)	P15 (68.6)	P50-P85 (91.5)	P15 (66.7)
10 years	P95 (100.0)	P15 (57.1)	P95 (87.5)	P15 (58.8)
11 years	P95 (100.0)	P15 (80.0)	P15-P50 (83.9)	P15 (37.5)

Note: % represents classification agreement of KTK3 within KTK4, lowest agreement in case of n $\neq 0$

Organised by gender

When organised by gender, Pearson correlations between KTK3 and KTK4 were .97 for both boys and girls (Table 1). Agreement between classifications was almost perfect (Kappa = .83) for boys and substantial for girls (Kappa = .65) (Table 2). Classification agreement was consistently between 80 and 100% for boys and between 37.5 and 83.9% for girls. The lowest agreement was found for P15 (Table 3).

Organised by age group and gender

Correlations between KTK4 and KTK3 scores for all age*gender groups was between r = 0.96 and 0.98 (Table 1). Agreement between both measures ranged from substantial (Kappa = 0.69) in the 9 year old boys to almost perfect (Kappa = 0.83) in the 11 year old boys. In the girls, agreement was substantial throughout (Kappa = 0.64 – 0.79) (Table 2). The lowest level of agreement was found in the P15 category for girls between 8-11 years and in the P85 category for girls aged 6 and 7 years. For boys, agreements were low (<60%) at 6 years for P5 and P15, at 8 years for P85 and at 10 years for P15 (Table 3).

DISCUSSION

Currently, no peer-reviewed research has documented the validity of a shortened form of the KTK (i.e. KTK3, removal of the HH subtest) for measuring motor competence in children aged 6-11 years, despite its frequent use in both educational and sporting settings. The findings from this study demonstrate that the KTK3 displayed near-perfect correlations with the KTK4, with the excluded component only accounting for five percent of the total variance in MQ sum scores. The overall classification accuracy of the KTK3 was very high, however inconsistencies were observed when organizing participants according to their gender and further by age. Specifically, the lowest agreement between the KTK3 and KTK4 occurred for girls aged 6-7 years (P15) and 8-11 years (P85); and boys aged 6 (P5 and P15), 8 (P85) and 10 years (P15). The findings from this study have important implications for the use of a shortened form of the KTK for measuring motor competence in children by providing further insight into its discriminative validity and classification accuracy.

When assessing motor competence within an educational or sporting setting, it is common for researchers and practitioners to be placed under significant time pressure when completing multiple assessments. For example, within talent identification protocols, it is imperative that the assessment protocol allows for a large sample of players to be measured in a short period of time, as many programmes can have in excess of 200 youth athletes (Deprez, Vaeyens, Coutts, Lenoir & Philippaerts, 2012; Deprez et al., 2015; Vaeyens et al., 2006). As a result, researchers have shifted away from traditional measures such as the BOT-2 complete form that require a considerable amount of time to complete (45-60 min) to shorter testing batteries such as the KTK and BOT-2 short form (15-20 min), which are undoubtedly more practical (Fransen et al., 2014b). However, it is important to note that within the KTK, the HH component requires approximately ten minutes to administer per participant, while the WB, JS and MS subtests require approximately ten minutes in total. As such, the removal of the HH component presents the potential to significantly increase the practicality of the KTK. It is also important to note that HH may present an increased risk of injury to developing children by placing high load on a single foot when landing from a height of more than 1 m. These practical considerations should be taken into account when selecting a motor competence testing protocol within general and sport-specific populations in the future.

Interestingly, several researchers have recently adopted the use of the KTK3 protocol outlined in the present study (Deprez et al., 2015; Mostaert et al., 2016; Opstoel & Pion et al., 2015; Pion et al., 2015; Vandendriessche et al., 2012). It is likely that both of the factors identified above have played a role in adopting such a protocol i.e. to increase practicality of the protocol and the potential to minimize risk of injuries via removal of the HH component. However, while these researchers have chosen to adopt the KTK3 protocol, this study presents the first data to highlight the applicability of the KTK following the removal of the HH component.

Kiphard and Schilling (1974) proposed that the KTK could be a useful tool to identify those children with poor (MQ < 85) or excellent (MQ > 115) motor competence. However, in this study, MQ scores were not used as they require all four KTK subtests to be derived from the MQS tables in the KTK handbook. Therefore, this study used a different approach, that can easily be replicated across other studies and in practice, due to the use of percentile scores. Because of the excellent statistical power of this study, KTK scores were subdivided into children at severe risk of developing poor motor competence (P5), children at risk of developing poor motor competence (P15), children with below average to average motor competence (P15-50), children with average to above average motor competence (P50-85), children with good motor competence (P85) and children with exceptional motor competence (P95). A similar approach was used to assess convergent validity between the BOT Short Form and KTK by Fransen et al. (2014b). This study has identified that when KTK3 and KTK4 were compared across children aged 6-11 years, agreement in MQS scores were very high for P5, P15-50, P50-85 and P95 groups with lower agreement for P15 and P85 categories. These findings are not surprising given that the KTK4 has previously been reported to possess limited classification sensitivity within these categories (i.e. children at risk and children with good motor competence) when compared to the BOT-2 short form motor competence test (Fransen et al., 2014b). Collectively, these results highlight that KTK3 retains strong validity to identify those children who are at a severe risk of developing poor motor competence and require additional motor competence training (P5); and further remains a strong talent identification tool for exceptionally gifted children (P95).

It is important to note that when separated into individual gender and age groups, variations in classification accuracy became apparent and these findings may help researchers and practitioners to select between the KTK3 and KTK4 protocols when assessing motor competence in specific cohorts. Specifically, when the data were organised by gender into separate cohorts of boys and girls, the KTK3 retained less accuracy when classifying girls than boys across all age groups and classifications (classification errors of 37.5 – 83.9% and 80 – 100% for girls and boys, respectively). When the girls were further categorised into separate age groups, the lowest accuracy occurred within 8-11 year old girls for P85 and within 6-7 year old girls for P15. Comparatively, while the male cohort generally exhibited higher classification accuracy than the female cohort for KTK3, the results also identified variation across age groups. Most notably, agreement between the two protocols within the boys cohort were lowest at 6 years (P5 and P15), 8 years (P85) and 10 years (P15). While agreement within these individual age/gender categories was poor between KTK3 and KTK4 (50-70%), there were no cases in which the KTK3 protocol classified a child to be more than one category either side of their KTK4 classification, highlighting the overall acceptable agreement that is retained within the KTK3 protocol.

This is the first study to investigate alternative KTK protocols, however, it should be noted that the current study was presented with several limitations which can be addressed within future research. Firstly, the current data pertains only to children aged between 6-11 years and further research is required to determine if other age and gender groups could be tested with KTK3 while retaining acceptable validity. Additionally, this study did not collect data using alternative motor competence testing batteries such as the BOT-2 short form, MOT 4-6 and M-ABC-2 protocols and further research would be required to determine whether agreement between KTK and these protocols is retained when HH is removed. While the KTK4 has previously been compared with the BOT-2 short form and MOT 4-6 protocols, it was highlighted that multiple tests should be administered in order to accurately assess motor competence (Bardid et al., 2016; Fransen et al., 2014b). As such, the removal of a subtest from a motor competence testing battery would appear counter intuitive. However, the results of this study show that only a small amount of accuracy is lost when removing the HH component and the potential to minimize risk of injury and increase practicality is worthy of consideration for future researchers and practitioners.

CONCLUSION

Overall, the classifications produced by the KTK3 protocol were in good agreement with KTK4, however there was poor classification accuracy within several gender/age classifications; girls aged 8-11 years (P85) and 6-7 years (P15); boys aged 6 years (P5 and P15), 8 years (P85) and 10 years (P15). When selecting a KTK protocol, researchers and practitioners should consider that the KTK4 has superior validity over the KTK3. However, KTK3 retains relatively high accuracy and presents the potential to minimize the risk of injury to children through the removal of the hopping for height component. Most importantly, an ideal motor competence testing battery should be able to identify low performers as well as high performers so that remediation strategies can be implemented for the low performers while talented individuals can be identified within a sports setting.

Although further research on the applicability of the KTK3 within different settings (talent identification, clinical populations, education etc.) is needed, the KTK3 protocol retains very high accuracy within the P5 and P95 classifications and therefore appears to be a suitable motor competence assessment tool for children aged between 6-11 years.

REFERENCES

Bardid, F., Huyben, F., Deconinck, F. J. A., De Martelaer, K., Seghers, J., & Lenoir, M. (2016). Convergent and divergent validity of the KTK and MOT 4-6 motor tests in pre-schoolers. *Adapted Physical Activity Quarterly, 33*(1), 15-32.

Barnett, L. M., Stodden, D., Cohen, K. E., Smith, J. J., Lubans, D. R., Lenoir, M. . . . Morgan, P. J. (2016). Fundamental movement skills: an important focus. *Journal of Teaching in Physical Education, 35*(3), 219-225.

Bruininks, R. H., & Bruininks, B. D. (2006). BOT-2: Bruininks-Oseretsky Tests of Motor Proficiency. Minneapolis, MN: AGS Publishing.

Clark, J. E., & Metcalfe, J. S. (2002). The mountain of motor development. In: Clark, J. E., Humprehy, J. H. Motor development: research and review (Vol 2): Reston (VA): National Association of Sport & Physical Education, 163-90.

Deprez, D. N., Vaeyens, R., Coutts, A. J., Lenoir, M., & Philippaerts, R. M. (2012). Relative age effect and YYIR1 in youth soccer. *International Journal of Sports Medicine, 33*, 987–993.

Deprez, D. N., Fransen, J., Lenoir, M., Philippaerts, R. M., & Vaeyens, R. (2015). A retrospective study on anthropometrical, physical fitness, and motor coordination characteristics that influence dropout, contract status, and first-team playing time in a high-level soccer players aged eight to eighteen years. *Journal of Strength & Conditioning Research, 29*(6), 1692-1674.

Fransen, J., Deprez, D., Pion J. A., Tallir, I. B., D'Hondte, E. Vaeyens, R., ... Philippaerts, R. M. (2014a). Changes in physical fitness and sports participation among children with different levels of motor competence: A 2-year longitudinal study. *Pediatric Exercise Science*, *26*, 11-21.

Fransen, J., D'Hondt, E., Bourgois, J., Vaeyens, R., Philippaerts, R. M., Lenoir, M. (2014b). Motor competence assessment in children: Convergent and discriminant validity between the BOT-2 short form and KTK testing batteries. *Research in Developmental Disabilities, 35*(6), 1375-1383.

Gallahue, D. L., & Ozmun, J. C. (2006). Understanding motor development: infants, children, adolescents, adults (6th ed.): McGraw-Hill.

Haga, M. (2009). Physical fitness in children with high motor competence is different from that in children with low motor competence. *Physical Therapy, 89*(10), 1089-1097.

Hands, B. (2008). Changes in motor skill and fitness measures among children with high and low motor competence: A five-year longitudinal study. *Journal of Science & Medicine in Sport. 11*(2), 155-162.

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). Movement Assessment Battery for Children-2. London: Harcourt Assessment.

Kambas, A., Venetsanou, F., Giannakidou, D., Fatouros, I. G., Avloniti, A., Chatzinikolaou, A. . . . Zimmer, R. (2012). The motor-proficiency-test for children between 4 and 6 years of age (MOT 4-6): an investigation of its suitability in Greece. *Research in Developmental Disabilities*, *33*(5), 1626-1632.

Kiphard, E. J., & Schilling, F. Körperkoordinationstest für Kinder. (1974, 2007). Weinheim: Beltz Test GmbH.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 159-174.

Lenoir, M., Vandorpe, B., D'Hondt, E., Pion, J., Vandendriessche, J., Vaeyens, R., & Philippaerts, R. (2014). KTK-NL Körperkoordinationstest für Kinder (Ernst Kiphard & Friedhelm Schilling) Herwerkte gehernormeerde en vertaalde uitgave van de KTK voor het Nederlandstalig gebied, SIG vzw, Destelbergen.

Mostaert, M., Deconnick, F., Pion, J., Lenoir, M. (2016). Anthropometry, physical fitness and coordination of young figure skaters of different levels. *International Journal of Sports Medicine*, *37*(7), 531-538.

Opstoel, K., Pion, J., Elferink-Gemser, M., Hartman, E., Willemse, B, Philippaerts, R. . . . Lenoir, M. (2015). Anthropometric characteristics, physical fitness and motor coordination of 9 to 11 year old children participating in a wide range of sports. *PLoS One*. *10*(5), e0126282.

Pion, J. A., Fransen, J., Deprez, D. N., Segers, V. I., Vaeyens, R., Philippaerts, R. M., & Lenoir, M. (2015). Stature and jumping height are required in female volleyball, but motor coordination is a key factor for future elite success. *Journal of Strength & Conditioning Research*, *29*(6), 1480-1485.

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1278-1284.

Rudd, J., Butson, M. L., Barnett, L., Farrow, D., Berry, J., Borkoles, E., & Polman, R. (2016). A holistic measurements model of movement competency in children. *Journal of Sports Sciences, 34*(5), 477-485.

Schulz, J., Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2011). Structural validity of the movement ABC-2 test: Factor structure comparisons across three age groups. *Research in Developmental Disabilities*, *32*(4), 1364-1369.

Stodden, D. F., Goodway, J. F., Langendorfer, S. J., Robertson, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor competence in physical activity: An emergent relationship. *Quest*, *60*(2), 290-306.

Utesch, T., Bardid, F., Huyben, F., Strauss, B., Tietjens, M., De Martelaer, K. . . . Lenoir, M. (2016). Using Rasch modeling to investigate the construct of motor competence in early childhood. *Psychology of Sport and Exercise*, *24*, 179-187.

Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., Vrijens, J., & Philippaerts, R. M. (2006). A multidisciplinary selection model for youth soccer: the Ghent youth soccer project. *British Journal of Sports Medicine, 40*(11), 928-934.

Vandendriessche, J. B., Vaeyens, R., Vandorpe, B., Lenoir, M., Lefevre, J., & Philippaerts, R. M. (2012). Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years). *Journal of Sports Sciences*, *30*(15), 1695-1703.

Vandorpe, B., Vandendriessche, J., Vaeyens R, Pion, J., Lefevre, J., Philippaerts, R., & Lenoir, M. (2011). Factors discriminating gymnasts by competitive level. *International Journal of Sports Medicine, 32*(8), 591-597.

Zimmer, R., & Volkamer, M. (1987). Motoriktest für vier-bis sechsjärige Kinder (manual). Weinheim, Germany: Beltz Test.