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A review of studies using the Körperkoordinationstest für Kinder (KTK)

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The Körperkoordinationstest für Kinder (KTK) (Kiphard & Schilling, 1974, 2007) is a standardized, norm-referenced measure used by physical therapists and occupational therapists in clinic and school practice settings to evaluate the motor coordination (MC) of 5- to 14-year-old children. To find out for which research purposes the KTK has been used and its reliability and validity, we conducted a systematic review. Searching five databases, we found 46 studies used the KTK over four decades. The KTK was widely used in Europe in children with typical and atypical development. The KTK was used to investigate associations, to test the effects of interventions and treatments, to identify or diagnose different factors, to evaluate MC and it was included in reviews of motor assessments. The KTK was reported to be a reliable measure, although only nine studies examined its validity or reliability in target populations. The KTK was considered a non-sport/skill-specific, easy-to-administer, had a scoring system that enabled cross-study comparisons but was limited to balance and locomotor aspects, had norm values that were outdated, and needed careful standardization. The KTK's validity for different purposes requires further evaluation.

Keywords: test battery, literature review

Introduction

In the 1960s, German child and youth psychiatrists E. J. Kiphard, and F. Schilling were interested in devising, for use in treating psychomotor deficits, a practical test that would indicate an individual's capacity for sensory-motor integration in order to control and coordinate the body (Kiphard and Schilling, 2007, 7–9). Children with brain disorders, in particular, seemed to have major difficulties in achieving the sensory-motor integration required to coordinate their bodies. If these deficits could be recognized early enough, a child could receive rehabilitation that would reduce negative compensation strategies and enable him or her to become integrated into society. After scrutinizing 150 activity test options and examinations administered to children, Kiphard and his German colleagues created the Hamm-Marburger Körperkoordinationstests, comprising six test items. After each test item was evaluated theoretically and in practice, the final Körperkoordinationstest für Kinder (KTK) with four test items was established

(Kiphard and Schilling, 1974, 2007). The test items are described in the Supplementary file 1 (Supplementary file 1).

Studies on the quality criteria and standardization of KTK were conducted in 1973-74 among children aged 5 to 14. The children comprised the 1228 standardization sample (the KTK norm group), 79 with confirmed brain disorder, 59 with suspected brain disorder, 79 with behavior disturbances, and 27 with speech disturbances. For the raw scores on the four test items, the test-retest reliability coefficients ranged between $0.80 \geq r \leq 0.96$, and for the total raw score, the reliability was 0.97. Validity was indicated through differentiation between children with typical and atypical development or disability. With the KTK, 91% of children with brain damage could be differentiated from children with typical development. The explained variance of the total score by the four test items ranged from 81% (age 6) to 98% (age 9), indicating high content validity. Internal structure validity according to factor analysis indicated that the four test items loaded on the same factor. The intercorrelations between the

four items ranged from 0.60 (WB/JS) to 0.81 (HH/JS).

The KTK has a long history and, in practice, we found that it is referred to quite a lot in the literature related to the study of childhood motor development. This allows us to hypothesize that the KTK is widely used today and adopted in disciplines and for purposes other than it was originally intended. If these hypotheses hold true, it is essential to analyze for which research purposes the KTK has been used and the reliability and validity of the KTK in these different studies. The purpose of our review was to analyze the use of the KTK in different studies by (1) describing the characteristics of the studies, (2) categorizing them according to their main purpose(s) and utilization of the KTK, and (3) describing the validity and reliability of the KTK in the target populations appended with the users' comments.

Methods

A systematic search of the literature to identify articles that reported on use of the KTK was conducted in January 2014 and updated in February 2015. We sourced the articles from the following databases: MEDLINE (ProQuest), PsycINFO (ProQuest), SPORTDiscus with Full Text (EBSCO), PubMed (Medline) and Web of Science (WoS). We used the search terms "KTK OR Körperkoordinations test OR Körperkoordinationstest" in the search strategy. We included studies if (1) a search term existed in the title or abstract, (2) the search term "KTK" did not refer to something other than the Körperkoordinations test or Körperkoordinationstest, and (3) the article had been published in an English- or German-language peer-reviewed journal.

The first author omitted duplicates from the lists of titles of the identified articles. The

first two authors then independently checked the titles and the abstracts to arrive at the selection of articles to be reviewed. For reliability, we calculated the percentage of agreement between the two reviewers. One hundred percent agreement was obtained. The first author read the included articles, extracted the material pertaining to the purpose of this review, and created a detailed summary table. The authors utilized the table when they categorized the articles according to their main purposes and use of the KTK test items in populations with typical development and with special needs. To establish the validity and reliability of the KTK and conclusions for using it for research purposes, we utilized the summary table and examined the whole texts for more exact information. Finally, we screened the reference lists of the retrieved articles for possible inclusion. All disagreements were resolved by consensus. This study was approved by the University of Jyväskylä. The articles included in this review were published in public academic journals.

Results

Characteristics of studies

A total of 192 potential titles were identified through the database searches: MEDLINE (ProQuest) 34, PubMed (Medline) 77, PsycINFO (ProQuest) 18, SPORTDiscus with Full Text (EBSCO) 12, and Web of Science - WoS 51. After duplicates were removed, a total of 42 articles satisfied the inclusion criteria. After an updated literature search across the five databases, we accepted four more articles, making a total of 46 articles for this review. An overview of the studies is shown in Table 1. A detailed table of the studies is available upon request from the first author.

Table 1. Summary of the included studies.

First author (year), location	Language	Topic	Design	Participants: age, grouping	The KTK scoring used	Discipline
Neühauser (1975) Germany	German	Review of psychomotor tests	Review	11 different assessments		Pediatry
Schenck (1978) Germany	German	Diagnostic efficiency of the KTK	Longitudinal	<i>N</i> = 140 (the comparison group) <i>N</i> = 224 with different impairments 5–12 years	HH and JS MQs	Pediatry
Lesigang (1982) Austria	German	Identify children with minimal cerebral palsy, and associations between motometric neuropsychological investigations and motor coordination	Cross-sectional	<i>N</i> = 192 (132 boys) Classes 1–4 from the special school for children with speech disturbances	MQs and classification into 4 categories	Neurology
Winneke (1982) Germany	English	Associations between gross motor coordination, lead-exposure and intellectual performance	Cross-sectional, comparative study, pair matched	<i>N</i> = 52 Mean age 8.5 years 26 with tooth-lead level (PbT < 3ppm)	MQs	Pediatry
Schneider (1984) United States	German	Effectiveness of intervention program on overall body coordination in dyslexic boys	Longitudinal (7.5 weeks) with pre- and post-measurements	<i>N</i> = 40 boys 12 year-olds 20 dyslexic	Raw scores and MQs	Education
Camacho-Araya (1990) Costa Rica	English	Assessment of stability and internal reliability of the Spanish version of the KTK	Reliability study	<i>N</i> = 280 Kindergarteners and 1 st and 2 nd graders	Original KTK items	Sport sciences
Smits-Engelsman (1998) The Netherlands	English	Suitability and comparison of the norms of Movement ABC and the KTK	Cross-sectional	<i>N</i> = 208 (87 boys) 5–13 years 74 with suspected motor problems (5–12 years)	KTK total scores	Pediatry
Jöhnk (1999) Germany	English	Introduction of methods for the evaluation of sensorimotor functions after traumatic brain injury	Discussion of 9 methods, longitudinal follow-up case-study	<i>N</i> = 17 One 11-years-old girl suffering from severe traumatic brain injury	MQ	Neuropediatry
Stieh (1999) Germany	English	Determine gross motor coordination of children with heart disease	Cross-sectional	<i>N</i> = 132 (67 boys) 5–14 years 102 (53 boys) with various forms of congenital heart disease	MQs	Pediatry

Laucht (2000) Germany	German	Developmental sequel of impacts of early <i>organic risk</i> (pre- and perinatal complications) and <i>psychological risk</i> on motor, cognitive and socioemotional outcomes	Cross-sectional	N = 347 (171 boys) prospective cohort	JS	Pediatrics
May (2001) Germany	German	Effects of regular Judo training	Intervention, Prospective controlled design	N = 33 boys 13–26 years 14 in judo group with multiple handicaps	Raw scores, MQs	Pediatrics
Graf (2003) Germany	German	Associations of overall body coordination and endurance performance	Cross-sectional, intervention	N = 906 (479 boys) 6-7 years 668 (341 boys) in intervention group	MQs	Sport sciences
Hebestreit (2003) Germany	English	Association of head size with whole-body coordination and the oxygen cost in cycling test	Cross-sectional	N = 54 (19 boys) 6–12 years 33 prematurely born	MQ	Neuropediatrics
Baumann (2004) Germany	German	Associations of ascertained results and motor development with ICD 10	Cross-sectional, clinical	N = 102 (79 boys) 5–13 years psychiatric patients	MQs	Neuropediatrics
Graf (2004) Germany	English	Associations between body mass index (BMI), PA and different motor tests of gross motor development	Cross-sectional	N = 556 (281 boys) Mean age 6.7 years	MQs	Sport sciences
Prätorius (2004) Germany	German	Differences in coordinative performances between children from socioeconomically diverse settings	Cross-sectional	N = 163 (85 boys) 6–13 years	MQs	Sport sciences
Steiss (2005) Germany	German	Comparison of neurodevelopment profiles examined by different tests	Cross-sectional	N = 58 (26 boys) 9–12 years 31 preterm infants	MQs	Neuropediatrics
Cools (2009) Belgium	English	Comparison of seven movement skill assessment tools	Review	The reviewed tools: MOT 4–6 Movement-ABC PDMS-2 KTK TGMD-2 MMT BOTMP-BOT-2	-	Sport Sciences

Gheysen (2008) Belgium	English	Impact of implant on the motor development of deaf children	Experimental	N = 79 (30 boys) 4–12 years 36 deaf	MQs	Pediatrics
Hanewinkel-van Kleef (2009) The Netherlands	English	Predictors of motor performance in children with joint hypermobility and motor problems	Cross-sectional, descriptive	N = 41 (22 boys) 5–12 years	Percentiles	Pediatrics
Van Aken (2009) The Netherlands	English	Determine motor performance of 22q11.(chromosome) deletion syndrome children	Cross-sectional, descriptive	N = 56 (28 boys) Mean age 9.6 years 28 in 22q11.DS group	MQs	Pediatrics
Martins (2010) Portugal, Azores Islands	English	Longitudinal associations and changes in gross motor coordination, BMI, PA and fitness during 5 consecutive years	Longitudinal (5 years)	N = 285 (143 boys) 6–10 years	Sum of the 4 tests' scores adjusted for age and sex	Sport sciences
Toftegaard-Stoekel (2010) Denmark	English	Associations between children's physical competence, bodily competence, BMI, and motor abilities, and comparison with the KTK normative material	Cross-sectional	N = 646 (338 boys) 6–7 years	MQ	Sport sciences
D'Hondt (2011b) Belgium	English	Short-term (2 years) effectiveness of 6–10 months obesity/overweight treatment program	Intervention Quasi Experimental, matched pairs	N = 72 (48 boys) 7–13 years 36 overweight/obese	Raw scores and MQ	Pediatrics
D'Hondt (2011a) Belgium	English	Differences in gross motor coordination in healthy-weight, overweight and obese children	Cross-sectional	N = 954 (454 boys) 5–12 years	MQ	Pediatrics
Graf (2011) Germany	German	Effects of the four-year-long Children's Health Interventional Trial (CHILT) - project on motor productivity and whole body coordination	Cluster-randomized-controlled-intervention-trial	N = 615 6–7 years 436 in intervention schools	MQs	Sport sciences

Kranz (2011) Switzerland	German	Effects of a grapho- and psychomotor treatment on motor coordination index	Experimental longitudinal with pre-, post-, and follow-up-test	N = 188 Mean age 4.1 years 68 in experimental group	Index-KTK	Sport sciences
Krombholz (2011) Germany	German	Changes in motor performance between years 2001 and 1973/1974 and 1977	Retrospective, cohorts	N = 375 in “Studie 1973”, 3–6 years N = 123 in “Studie 1974”, 5–6 years N = 644 in “Studie 1977”, 6–7 years N = 1532 in “Studie 2000”, 3–7 years	WB and JS raw scores	Sport sciences
V. P. Lopes (2011) Portugal, Azores Islands	English	Longitudinal relationships among motor proficiency, physical fitness and PA in 6- to 10-year-old children	Longitudinal (5 years)	N = 285 (143 boys) 6–10 years	MQ	Sport sciences
Vandorpe (2011) Belgium	English	Gender- and age-specific reference values for the gross motor coordination of Flemish children, compared with the norms of the original German standardization sample	Cross-sectional	N = 2470 (1297 boys) 6–12 years	Raw scores, MQ	Sport sciences
Vandendriessche (2011) Belgium	English	Variance in motor coordination by maturity, body size and fitness	Cross-sectional	N = 613 boys 181 aged 7 years 245 aged 9 years 187 aged 11 years	Raw scores	Sport sciences
Debraband (2012) Belgium	English	Age-related effects and correlations in timing abilities and conditions with motor skill proficiency	Cross-sectional	N = 80 (40 boys)	JS	Sport sciences
L. Lopes (2012) Portugal	English	Relationship between sedentary behaviour and motor coordination	Cross-sectional	N = 123 (103 boys) 9–10 years	MQ	Sport sciences
V. P. Lopes (2012a) Portugal, Azores Islands	English	Motor coordination, physical fitness and PA as predictors of the development of subcutaneous adiposity	Longitudinal (5 years 2002–2007)	N = 285 (143 boys) 6–10 years	MQ	Sport sciences
V. P. Lopes (2012b) Portugal	English	Association between motor coordination and	Cross-sectional	N = 7175 (3616 boys) 6–14 years	MQs	Sport sciences

		BMI across childhood and early adolescence				
Vandendriessche (2012) Belgium	English	Associations of young soccer players maturity status with their morphological measures, fitness, soccer-specific and non-specific motor coordination skills	Experimental, descriptive	<i>N</i> = 78 youth national soccer team players 15–16 years	WB, JS, MS	Sport sciences
D'Hondt (2013) Belgium	English	Short-term evolution in gross motor coordination according to weight status, and identifying factors, and prediction of future gross motor coordination	Longitudinal (2 years 2007–2009), matched pairs	<i>N</i> = 100 (48 boys) 6–10 years 50 overweight /obese	MQs	Sport sciences
Laukkanen (2013) Finland	English	Relationship between gross motor skills and PA analyzed with two different methods	Cross-sectional	<i>N</i> = 84 (38 boys) 5–8 years	MC	Sport sciences
V. P. Lopes (2013) Portugal	English	Associations between motor coordination and weight status, and relative risk of being overweight/obese based on the level of motor coordination	Cross-sectional	<i>N</i> = 6625 (3344 boys) 6–11 years	MQs	Sport sciences
L. Lopes (2013) Portugal	English	Relationship between gross motor coordination and academic achievement after adjusting for cardiorespiratory fitness, BMI and sociodemographics	Cross-sectional	<i>N</i> = 596 (315 boys) 9–12 years	MQs	Sport sciences
Martin-Diener (2013) Switzerland	English	Correlations between retrospectively assessed injury risk incidence rate, PA, aerobic fitness and motor coordination	Cross-sectional	<i>N</i> = 249 (126 boys) Mean age 7.9 years	MQs	Sport sciences

Ecard-Rocha (2013) Brazil	English	Relationship between motor characteristics, dermatoglyphics for physical qualities and brain electro of pre-and post-menarche girls	Cross-sectional, descriptive	N = 45 girls 10–14 years 21 identified as pre- menarche	MQs	Pediatry
Deprez (2014) Belgium	English	Model of development including maturity status, body composition and motor coordination	Longitudinal (5 years, 2007-2012)	N = 162 male soccer players, age 11-14 years	MC, WB,JS,MS raw scores	Sport sciences
Fransen (2014) Belgium	English	Validity between the BOTMP- BOT and KTK	Cross sectional	N = 2485 (1300 boys), 6-11 years	MQs	Sport sciences
Olesen (2014) Denmark	English	Descriptions of gender differences in motor skills, PA, ethnicity, parents education and preschool	Cross sectional	N = 607 (299 boys), mean age 5.8 years	MQs	Sport sciences
Freitas (2015) Portugal	English	Relationships between age, body size, fundamental motor skills and motor coordination	Cross sectional	N = 429 (213 boys), 7-10 years	MC, raw scores	Sport sciences

Notes: Small letters after the publication years in parentheses differentiate different publications in the reference list; The KTK refers to different editions of Kiphard, E.J., & Schilling, F. (1974) Körperkoordinationstest für Kinder. Beltz test, Weinham; In cases where all four KTK test items (Walking Backwards [WB], Hopping for Height [HH], Jumping Sideways [JS], Moving Sideways [MS]) were not used, the items are mentioned; MQ = Motor Quotient based on the KTK manual; MC = refers to MQ; PA = physical activity; MOT 4–6 = Motoriktest für vier- bis sechsjährige Kinder; Movement-ABC = Movement Assessment Battery for Children; PDMS-2 = Peabody Developmental Motor Scales- Second Edition; TGMD-2 = Test of Gross Motor Development Second Edition; MMT = Maastrichtse Motorik Test; BOTMP-BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency.

Of the 46 articles, 27 were cross-sectional, nine were longitudinal designs with duration ranging from 7.5 weeks to 5 years, four were quasi-/experimental studies, two were reviews with no empirical component, one article reported a cluster-randomized-controlled-intervention-trial, one utilized a prospective cohort, one was a retrospective design, and one was a reliability study. The articles were published between 1975 and 2015; 13 were in German. The 44 articles that reported empirical studies included between 17 (Jöhnk

et al., 1999) and 7,175 (V. P. Lopes et al., 2012b) participants with ages ranging from 5 to 26 years, and assigned to one to six groups. The total number of participants reported in the articles was 31,465. The studies were conducted in 11 countries: Germany ($n = 15$), Belgium ($n = 12$), Portugal ($n = 7$), representing different areas including the Azores and Madeira), the Netherlands ($n = 3$), Switzerland ($n = 2$), Austria ($n = 1$), Brazil ($n = 1$), Costa Rica ($n = 1$), Denmark ($n = 2$), Finland ($n = 1$), and the United States ($n = 1$).

Thirty-three articles reported the KTK MQs or percentile ranks based on the normative values given in the manual (Kiphard and Schilling, 1974, 2007). Of these articles, 20 provided categories of KTK performance, varying between MC disorder and very good MC. Six studies reported raw scores (Debrabant et al., 2012; Krombholz, 2011; V. P. Lopes et al., 2012b; Vandendriessche et al., 2012), and six articles reported only the scores for JS.

Categorization

The articles fell into six categories according to their main purposes and use of the KTK or some of the items in populations with typical development and with special needs (Table 2). Seventeen studies in populations with special needs used the KTK to investigate the associations between motor and other variables. Five of these studies investigated the associations between motor and other physiological variables, such as lead exposure (Winneke et al., 1982), the head size of children born prematurely and at term (Hebestreit et al., 2003), the neurodevelopment of preterm infants (Steiss et al., 2005), body function and composition of children with joint hypermobility (Hanewinkel-van Kleef et al., 2009), and the maturity statuses of national team soccer players (Vandendriessche et al., 2012). Twelve of the studies of populations with typical development focused on the associations between motor and other physiological variables, such as body composition (D'Hondt et al., 2011a; Freitas et al., 2015; V. P. Lopes, et al., 2012a; V.P. Lopes et al., 2012b; Martins et al., 2010; Olesen et al., 2015), physical activity and/or fitness (V. P. Lopes et al., 2011, 2012a; Vandendriessche et al., 2011), skeletal age (Freitas et al., 2015), injury risk (Martin-Diener et al., 2013), and dermatoglyphic characteristics as indicators of genetic predispositions for physical qualities at maturation (Ecard Rocha et al., 2013). Associations between the KTK measured motor and physiological-social variables were investigated in three studies of typical populations. Interest was directed at body

composition and leisure habits (Graf et al., 2004), sedentary and parental behavior (L. Lopes et al., 2012), and weight, sociodemographics, and behavioral factors (D'Hondt et al., 2011a). One study examined the associations between motor and psychological-physiological variables, such as perceptions of bodily competence and body mass index (Toftegaard-Stoeckel et al., 2010). Associations between motor and psychological-cognitive variables were reported in four articles. Two studies investigated psychiatric disorder markers in children with mental and behavioral disabilities (Baumann et al., 2004) and the IQ of children with chromosome deletion syndrome (Van Aken, Caeyenberghs et al., 2009). The two studies with typical populations examined performance in concentrated activities (Graf et al., 2003) and academic achievement (L. Lopes et al., 2013). Only one article reported on a study that examined associations between the KTK measured motor variables and factors pertaining to socioeconomic diversity (Prätorius and Milani, 2004).

The second biggest category of articles ($n = 7$) was composed of studies that examined the effects of interventions or treatments on motor outcomes measured with the KTK. Among studies of populations with special needs, the studied effects on motor outcomes were creative movement and pantomime (Schneider, 1984), judo training (May et al., 2001), cochlear implant (Gheysen et al., 2008), and multidisciplinary obesity/overweight treatment (D'Hondt et al., 2011b). Types of interventions or treatments in the studies with typical populations were health education and physical activity (Graf and Dordel, 2011), grapho- and psychomotor treatment (Kranz et al., 2011), and different predictive response timing conditions (Debrabant et al., 2012).

Five articles reported on the use of the KTK or some of its items for diagnosis or identification purposes in populations with special needs (Deprez et al., 2014; Laucht et al., 2000; Lesigang and Aletsee, 1982; Schenck and Deegener, 1978; Stieh et al.,

1999). Three articles were reviews that analyzed motoscopic (von Neühauser, 1975), sensorimotor function (Jöhnk et al., 1999), or movement skill (Cools et al., 2009) assessment methods. One review included the implementation of a diagnostic follow-up study (Jöhnk et al., 1999). Three articles reported on measurement evaluation studies. The KTK's reliability in Spanish children (Camacho-Araya et al., 1990), the suitability of the KTK test norms for Dutch children (Smits-Engelsman et al., 1998), and convergent and discriminant validity between

the KTK and the Bruininks-Oseretsky Test of Motor Proficiency 2 Short Form (BOT-2 Short Form; Bruininks and Bruininks, 2005; Fransen et al., 2014) were examined.

The smallest category was composed of two studies that focused on children's gross motor coordination per se. One study examined whether there was evidence of a decrease in motor performance (Krombholz, 2011), and the other study collected KTK reference values for a Flemish population (Vandorpe et al., 2011).

Table 2. Categorization of articles according to their main purposes and the use of the Körperkoordinationstest für Kinder.

	Typical populations	Special populations
Category:	First author (year)	First author (year)
Associations of Motor factors with		
Physiological variables	Martins (2010)	Winneke (1982)
	D'Hondt (2011a)	Hebestreit (2003)
	V. P. Lopes (2011)	Steiss (2005)
	Vandendriessche (2011)	Hanewinkel-van Kleef (2009)
	V. P. Lopes (2012a)	Vandendriessche (2012)
	V. P. Lopes (2012b)	
	Laukkanen (2013)	
	Martin-Diener (2013)	
	V. P. Lopes (2013)	
	Ecard-Rocha (2013)	
	Olesen (2014)	
	Freitas (2015)	
Physiological-social variables	Graf (2004)	
	L. Lopes (2012)	
	D'Hondt (2013)	
Psychological-physiological variables	Toftegaard-Stoeckel (2010)	
Psychological-cognitive variables	Graf (2003)	Baumann (2004)
	L. Lopes (2013)	Van Aken (2009)
Social variables	Prätorius (2004)	
Intervention or treatment effectiveness on motor outcomes	Graf (2011)	Schneider (1984)
	Kranz (2011)	May (2001)
	Debraband (2012)	Gheysen (2008)
		D'Hondt (2011b)
Diagnosis or identification		Schenck (1978)
		Lesigang (1982)
		Stieh (1999)
		Laucht (2000)
		Deprez (2014)
Review of methods	Neuhauser (1975)	
	Cools (2008)	
plus diagnosing		Jöhnk (1999)
Measurement evaluation	Camacho-Araya (1990)	Smits-Engelsman (1998)
	Fransen (2014)	
Motor evaluation	Krombholz (2011)	
plus measurement evaluation	Vandorpe (2011)	

Validity and reliability of the KTK

Nine studies reported validity or reliability scores for the KTK in their target populations. Overall, the validity or reliability scores were reported to varying degrees of accuracy in these studies. Convergent and discriminant validity was reported in two studies. The KTK total score showed moderate correlations with the Movement ABC total score (Henderson and Sugden, 1992) ($r = 0.62\text{--}0.65$) and the BOT-2 Short Form total score ($r = 0.61\text{--}0.64$) in the different samples of 5- to 13-year-old Dutch and 6- to 11-year-old Belgian children, respectively (Fransen et al., 2014; Smits-Engelsman et al., 1998). When the test items, subsections, or composites were scrutinized separately, the lowest correlations were found between the KTK MS and Movement ABC balance ($r = 0.23$, children without known motor difficulties) and the KTK MQ and BOT-2 Short Form fine motor composite score ($r = 0.25$, total sample of Belgian children). Correlations were strongest between the WB and Movement ABC Balance ($r = 0.59$, children with known difficulties) and the MQ and BOT-2 Short Form gross motor composite score ($r = 0.62$, group of 6–7-year-olds). Further, the percentages of children with typical development falling below the 15th percentile were 29% for the KTK versus 16% for the Movement ABC, and the corresponding percentages for children with known difficulties were 68% for the KTK versus 59% for the Movement ABC (Smits-Engelsman et al., 1998). The percentages of children classified into score categories lower than the 5th and 15th percentiles and higher than the 85th and 95th percentiles were examined in a Belgian population. The results showed that the classification accuracy of the KTK was moderate for the 15th percentile ($\kappa = 0.42$) and fair for the 5th, 85th, and 95th percentiles ($\kappa = 0.31$, $\kappa = 0.33$, $\kappa = 0.33$, respectively). Fifty percent of children classified in ≤ 15 th percentile by the KTK were likewise classified by the BOT-2 Short Form (Fransen et al., 2014).

Test-retest reliability correlations for the KTK in their target populations were reported

in seven studies. Overall, the reliability coefficients ($r = 0.60\text{--}0.99$) showed moderate to high reliability (Camacho-Araya et al., 1990; Freitas et al., 2015; V. P. Lopes et al., 2011; 2012a, 2012b; Martins et al., 2010). Some studies reported reliability scores for the KTK total score and/or each test item separately. The highest re-test correlations were found for the total score ($r = 0.89\text{--}0.94$) and the lowest for the WB ($r = 0.77\text{--}0.79$) (Camacho-Araya et al., 1990; Olesen, et al., 2014). Internal consistency estimated with Cronbach's alpha was 0.95 (Camacho-Araya et al., 1990). Inter-rater reliability with a double Latin square design (two raters, two groups of subjects, two ways of giving directions and/or scoring, and re-testing after 8 days with the two raters switching the scoring method and the group of participants) was also high ($r = 0.90\text{--}0.99$). Analysis of variations indicated significant sources of variation ($F > 52.13$) by sex, grade, group of children, and treatment in samples ($n = 120$ and 90) of Brazilian children (Camacho-Araya et al., 1990).

The following comments on the validity and/or reliability of the KTK were extracted from 13 papers and divided as follows: (1) The KTK can overestimate the number of children identified as having MC impairment (Hanewinkel van Kleef et al., 2009; Smits-Engelsman et al., 1998). (2) The KTK items represent movement product scores of balance and locomotor skills, and thus neither assesses MC all-inclusively nor is suitable for the assessment of MC development in children with clinical psychiatric disorders (Bauman et al., 2004; Cools et al., 2009; Jöhnk, 1999; Lesigang and Aletsee, 1982; V.P. Lopes et al., 2012a; Neuhaüser, 1975). (3) The norms were collected a long time ago and solely from German children. Thus, the cutoff scores were not heterogeneous enough to differentiate MC development at the low and high ends of the score distribution (V. P. Lopes et al., 2013; Prätorius and Milani, 2004; Schenk and Deegener, 1978; Vandorpe et al., 2011).

Discussion

This review aimed to analyze studies that used the KTK test battery (Kiphard and Schilling, 1974, 2007). We identified 46 studies published in peer-reviewed articles over 40 years. The oldest paper (von Neühauser, 1975) reviewed motoscopic methods. Three articles were published in the 1980s, four in the 1990s, 12 in the 2000s, and 25 in the 2010s. The studies were mainly European. Since the KTK was created in Germany, the assessment's popularity in German-speaking countries was expected. A team of researchers reported on seven studies that had been conducted among 6- to 12-year-old Portuguese children (L. Lopes et al., 2012; 2013; V.P. Lopes et al., 2011, 2012a, 2012b, 2013; Martins et al., 2010). Two studies were from Latin America (Camacho-Araya, 1990; Ecard Rocha et al., 2013) and only one (published in German) from the United States (Schneider, 1984). To improve international comparisons, we recommend wider use of the KTK. Translation of the KTK manual into English might facilitate use in other cultures.

Overall, the sample sizes reported in the empirical studies varied according to the context and purpose. The number of participants, ranging from 17 to 347, in the studies of populations with special needs was lower than in the studies with typical populations (range 45–7175). The KTK was most commonly used among children aged 6–12 years; 29 empirical studies investigated individuals between this age range. Since the KTK was standardized for 5- to 14-year-olds, its use in age groups outside this range, without ensuring assessment reliability in the target population, is questionable (Kranz et al., 2011; May et al., 2001). Eight different definitions, ranging from neutral ones, such as “scores” (e.g., Smits-Engelsman et al., 1998), to very specific ones, such as “dynamic balance” (e.g., D’Hondt et al., 2011a), were reported in the studies to describe the KTK outcomes. This indicates that the KTK was interpreted to measure somewhat different aspects. This finding strengthens the view that various terms exist in the literature to describe

general and specific aspects in the motor domain and that uncertainty exists regarding an optimal definition (Logan et al., 2014). However, the fact that the KTK was considered a suitable battery for various purposes across such different fields as physical education, sport, health sciences, medicine, and biomechanics can be interpreted as strength of the KTK.

In the majority of the studies, the KTK results were reported as age- and gender-standardized MQs calculated from the four items and variously classified as indicators of the motor status of the individuals tested. Producing MQ outcomes was seen as a system of scoring that describes individuals' global MC in meaningful categories, and allows comparison with results from other studies (V. P. Lopes et al., 2012b; Toftegaard-Stoekel et al., 2010). Since Kiphard and his colleagues developed the KTK in 5- to 14-year-old children, (Kiphard and Schilling, 2007, p. 7), it was logical that all 27 studies with typical populations were implemented in school or kindergarten settings. Perhaps, the KTK is suitable for schools, because it is reasonably quick and easy to administer. The participant groups in the 17 studies of populations with special needs differed in terms of special features. The KTK, since it is not sport-specific, was regarded as a suitable instrument for measuring the general motor level of different individuals and in special circumstances (Vandendriessche et al., 2012; Vandorpe et al., 2011).

The studies fell into six categories according to their main purposes and use of the KTK. Categorizing the studies was challenging due to the varying variables, such as background factors, field test, or interview outcomes and laboratory test samples, used in them. The biggest category was composed of studies that reported associations of MC with other factors. Of these associative studies, most investigated physiological factors. The studies frequently focused on children's body composition and physical activity or fitness, which could be expected in view of the global concern over the trend toward unhealthy weight and increased physical inactivity

among children (Leech, et al., 2014). Surprisingly, only two articles in the category of intervention or treatment effectiveness studies reported on the implementation of programs promoting a healthy eating or increased physical activity (D'Hondt et al., 2011b; Graf and Dordel, 2011). Overall, the KTK was used in different and multifaceted designs to provide motor domain outcomes among other variables. As expected, this was the case in the studies of populations with special needs, where the designs differed widely. Since the KTK was developed for screening purposes, it was reasonable that we identified a category of studies that mainly diagnosed or identified different medical factors, including motor variables measured by the KTK. Scrutiny of the historical continuum of the studies that used the KTK revealed that the use of the KTK has now spread from special fields of medicine to education and the sport sciences.

On the whole, the KTK was deemed a “thoroughly” standardized and validated tool, and was given as an appendix in the articles along with a reference to the KTK manual. An undesired finding was that only nine studies examined the KTK's validity or reliability in the target populations. Overall, the re-test coefficients indicated good reliability for the test battery. Notwithstanding, we suggest that feasibility studies that ensure satisfactory validity and reliability be carried out in target populations. This is important in populations with special needs, in whom symptoms, morbidity status, and other individual features vary widely, and populations at an early phase of motor development, when intra- and inter-individual differences are large and development is rapid (Gallahue et al., 2012). In fact, many authors criticized the validity or reliability of the KTK (Baumann et al., 2004; Jöhnk et al., 1999; Lesigang and Aletsee, 1982), but for some reason did not report addressing these concerns in their target groups. For example, the KTK was not seen as an inaccurate method of diagnosing minimal cerebral palsy (Lesigang and Aletsee, 1982) or estimating the number of children suffering from brain impairments (Smits-Engelsman et

al., 1998). Consequently, the use of additional tests was advised, including by authors who questioned the validity of the KTK because it produces movement product scores and is limited to balance and locomotor aspects among the fundamental motor skills (Cools et al., 2009; V.P. Lopes et al., 2012a; Neuhäuser, 1975). We agree with this view. Recently, researchers have started to combine different test batteries for more specific measures of MC and fundamental motor skills to compensate for the limitations imposed by a single test battery (Freitas et al., 2015). We support this trend.

The few studies that tested the validity of the KTK all came to the conclusion, regardless of the specific population studied, that the number of children identified as having motor difficulties was considerably higher for the KTK than for the other test batteries designed for the same purpose (Fransen et al., 2014; Hanewinkel van Kleef et al., 2011; Smits-Engelsman et al., 1998). Children's living conditions and lifestyles have changed from the 1970s to today. Therefore, classifying children's motor characteristics based on normative values collected four decades ago may give a different picture of the present-day reality, as was discussed in the literature (Baumann et al., 2004; Smits-Engelsman et al., 1998; Vandorpe et al., 2011). As confirmation, the KTK showed moderate validity when the test discriminated between children with relatively poor motor proficiency and those with average to good proficiency but only fair validity when the KTK was used to classify children with high or very poor proficiency. This may indicate that the KTK categorizes children incorrectly (Fransen et al., 2014). Consequently, careful interpretation of norm-referenced performances is advised, since normative data are often based on limited samples (Cools et al., 2009). This notion applies to the KTK, as its normative data were collected from children who shared the same culture across a limited geographic area. Possible methods for remedying this limitation include collecting international reference values or examining cultural sensitivity before using the test battery

in a particular region (Tripathi et al., 2008). In sum, the results of this review study lead us to recommend to carefully pre-examine the potential test batteries and/or test items to be used or combined before choosing a particular measure for a particular purpose. Since the original aim of the KTK was to identify and, where necessary, recommend further evaluations of children with brain damage, as well as assist in designing appropriate means of rehabilitation for this specific group, researchers and others who use the battery for purposes unrelated to this aim need to include the evaluation of validity for their target groups.

Perspective

The KTK was originally developed to identify children with brain damage. It is now used as a measure for MC for various research purposes in children with different development in multiple contexts. From the users' perspective, the KTK was regarded to be (1) easy to administer, (2) usable in children with and without impairments, (3) already in wide use in Europe and becoming increasingly popular, (4) carefully standardized in German population, (5) a non-sport/skill-specific measure, and (7) based on a meaningful scoring system that enables cross-study comparisons. The KTK was criticized because it is limited to balance and locomotor aspects, has outdated norms with cutoff scores that are not heterogeneous enough to differentiate MC development. The KTK may overestimate the number of children identified as having MC problems. Based on the review conducted, we recommend the use of KTK raw scores when the interest is to follow MC development and when reporting research. We also warrant examination of the validity of the KTK for different purposes and in different target populations.

Supplementary files

Supplementary file 1. Description of the test items (1–4) and scoring of the The

Körperkoordinationstest für Kinder (KTK) (Kiphard and Schilling, 1974, 2007).

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