# Physical education

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# Chapter 4

## Development of a tool to assess fundamental movement skills in applied settings.

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## ABSTRACT

The main aim of this study was to evaluate a new combination of test items on its practical use as a tool for determining the broad spectrum of fundamental movement skills performance in six- to ten- year-old primary school children. For this purpose 1121 primary school children were assessed during their regular PE class using three test items of the Korper Köordinations Test für Kinder (KTK), i.e. walking backwards (WB), moving sideways (MS), jumping sideways (JS), and an eye hand coordination test item (EHC). Univariate General Linear Model analyses were used to elucidate main and interaction effects of sex and age and Pearson's correlation coefficients to represent interrelationship between the raw test item outcomes. Movement quotients (i.e. MQKTK-3 and MQKTK-3 + EHC) were converted based on the raw scores and used to classify children. Accordingly, percentage of agreement and Cohen's kappa between both classifications was determined. Alpha was set at 0.05.

Significant effects for sex and age were found. Girls outperform boys on WB and boys outperform girls on EHC ($P < 0.05$). On all test items children of a certain age group scored better than their 1-year younger peers, except at WB between 10 and the 8- and 9-year olds and at MS and JS between 9-year olds and 10-year olds. Moderate positive associations between the test items were found ($P < 0.05$). An 80.8% agreement of classification of children was found based on the MQKTK-3 or the MQKTK-3 + EHC.

The KTK-3 + EHC appear to adequately cover different aspects of the fundamental movement skills. It provides practitioners working with young children a tool that can objectively assess a broad range of fundamental movement skills within applied settings. This offers opportunities to better meet children's individual developmental needs and evaluate the effectiveness of professionals' own practices.


Keywords: Motor skill performance, FMS assessment, child, KTK-3

## INTRODUCTION

All children could benefit from an instrument which assesses a child's fundamental movement skills (FMS). Such an instrument would provide opportunities for professionals working with young children in the context of sport and education to 1) have a more objective understanding of children's skills, 2) better meet children's developmental demands, and 3) analyse the effectiveness of their interventions. Currently, there are several instruments, which can measure children's FMS performance level, e.g. the Movement Assessment Battery for Children 2 (Henderson et al., 2008), the Bruininks-Oseretsky Test for Motor Proficiency 2 (Bruininks & Bruininks, 2005), and the Test of Gross Motor Development (Ulrich, 1985,2000). Most of these instruments focus on identifying children with fundamental movement skill development disorders and are rather time-consuming. Yet, in the context of sport and physical education an instrument for measuring FMS that covers not only children at risk but rather a broad performance spectrum in only limited time can be of great value (Vandorpe et al., 2011).

FMS are mainly build up by gross motor coordinative skills which are the building blocks for the more specific sports skills learned at later developmental stages (Clark, 2007; Catuzzo et al., 2015; Loprinzi et al., 2015; Loyd et al., 2014). Specifically adequate FMS are considered as a requirement for functioning in regular daily activities (Henderson et al., 2008), and a positive element to stimulate the initiation and maintenance of physical activity (Stodden et al., 2008). It includes locomotor skills (e.g. walking, running, hopping), balance / stability skills (e.g., balancing, turning, dodging), and object control (e.g. throwing, catching, kicking) (Gallaheu et al., 2012). From around the age of six to ten, typically developing children are in a sensitive stage to improve these FMS (Clark, 2007; Platvoet et al., 2016). Of course, also after age ten children still develop their FMS but not as fast as before (Ahnert et al., 2007; Franssen et al., 2014; Vandorpe et al., 2011). Results from a longitudinal study showed moderate to high long-term stability of FMS performance level from elementary school until early adulthood (Ahnert et al., 2009), and the level of motor competence at age nine and ten year olds was related to their physical activity levels 32 months later (Haga, 2009). Therefore, to our beliefs it is relevant to develop an instrument that can be used to assess especially six to ten year old's FMS which can be used to predict children's possible performance and physical activity levels in early adulthood. Although monitoring children's FMS have several advantages, currently the implementation of FMS measurement in settings like physical education and sport training is rather limited and the number of large-scale longitudinal studies on this topic are scarce (Loyd et al., 2014). A reasonable explanation is that still most existing instruments score low on feasibility aspects (instruction and demonstration are not short and simple) and / or have too many test items, which makes testing time consuming (Cools et al., 2009).

It was suggested by our colleagues (Vandorpe et al., 2011; Ahnert & Schneider, 2007) that from all the available measurements the Korper Köordinations Test für Kinder (KTK) might be of added value in the determination of a part of children's FMS. The KTK measures especially the locomotor and balance / stability skills of children Kiphard & Schilling, 1974, 2007), and allows a relatively straightforward and objective evaluation with limited interference of physical fitness (e.g. strength, speed, endurance and flexibility; (Vandorpe et al., 2011)). The KTK is one of the few FMS measurements that comprises the whole performance spectrum (Fransen et al., 2014). For that reason it is not only suitable to identify children with motor disorders, but also to distinguish typically developing children's performances. Moreover, the test is also valuable to determine the effectiveness of interventions (Cools et al., 2009). The KTK measures FMS by means of four test items: walking backwards, jumping sideways, moving sideways and hopping for height. Recently, our colleagues (Novak et al., 2016) showed a strong correlation between the KTK motor quotient (MQ) scores based on all four subtests and the KTK MQ scores when hopping for height was excluded ($r = .98$, $p < 0.001$). The KTK without hopping for height is suggested to be more applicable in educational and sport settings, since hopping for height is a time-consuming test item including a risk for getting injured (e.g. ankle sprain).

Although the KTK measures two of the three important FMS, it lacks a test item focusing on object control. This construct is considered as highly important for motor behaviour in daily life and specifically for performance in (ball and racket) sports (Butterfield et al., 2012). Consequently, adding a valid and reproducible test item to the KTK-3 that 1) measures this construct, 2) covers the broader performance spectrum of primary school children, and 3) only needs limited administering time, seems beneficial. The eye hand coordination test proposed by our colleagues (Faber et al., 2014) might fulfil this purpose. This test measures the level of controlling a ball while conducting repetitive movements (i.e., throwing and catching) in a time-constraint task of only 30 seconds. Moreover, earlier studies confirmed its capability to discriminate between children with different motor performance levels (Faber et al., 2014; Faber et al., 2017). The KTK-3 together with the inclusion of Faber's eye hand coordination test ensure a broader perspective on a child's FMS. It responds to the necessity of using multiple tests to accurately assess FMS performance without being time-consuming (Fransen et al., 2014; , Bardid et al., 2015; Logan et al., 2017).

Still, the KTK-3 with Faber's eye hand coordination test (i.e., the KTK-3 + EHC) to measure FMS performance needs to be evaluated for further practical use as a tool for determining the broad spectrum of FMS performance in six to ten year old primary school children. More specifically, the main aim was to study the effect of age and gender on the item scores, the interrelationships between the test items and the use of a motor quotient to classify into a performance category.

## MATERIALS & METHODS

### *Ethical statement*

This study procedure was approved by the ethical advisory committee at the Faculty of Health of the HAN university of applied sciences (reference number EACO 17.12/89). All parents were informed by the schools prior to the testing and were asked to communicate with the school in case they did not want their child(ren) to participate. All data were anonymously recorded in a secured dataset.

### Design

A cross-sectional study design was used in which primary school children were assessed between February and March 2017.

### Participants

Participating children were recruited at 13 regular primary schools in the Netherlands. To obtain a representative sample a selection of schools situated in rural and more urbanized areas in four different provinces of the Netherlands was made. A total of 1121 children, of which 559 boys and 562 girls, of the third through sixth grade class were included. Injured children were excluded. See Table 1 for more details about the participants.

**Table 1.** Participants' characteristics

| | | Primary school (n = 13) | | |
|---|---|---|---|---|
| | | **Total group** | **Boys** | **Girls** |
| N | | 1121 | 559 | 562 |
| Age group (n) | 6 | 192 | 89 | 103 |
| | 7 | 265 | 121 | 144 |
| | 8 | 266 | 143 | 123 |
| | 9 | 277 | 157 | 120 |
| | 10 | 121 | 49 | 72 |

Note 1. A child was classified within a age group corresponding to the actual age at the day of testing (e.g. a child was classified as six year old from 6.00 through 6.99)

### Fundamental movement skill assessment

The assessment of the children's FMS, consisted of four test items, i.e. three test items of the KTK short form, walking backwards (WB), moving sideways (MS) and jumping sideways (JS), and Faber's eye hand coordination test (EHC). The standardization of all test items is captured in protocols, which includes a detailed description of materials, set-up, assignment, demonstration, training phase, testing phase and registering test scores (Kiphard & Schilling, 2007; Faber et al., 2014). The test-retest reliability of the test items is considered good; WB 0.80, MS 0.84, JS 0.95, EHC 0.87 (Kiphard & Schilling, 2007; Faber et al., 2014).

*Walking backwards (WB)*

The children were instructed to walk backwards three times along of three balance beams (3 trials x 3 beams) with the same length (3 m) but differences in width (6 cm, 4.5 cm and 3 cm). The number of successful steps was scored as final raw outcome with a maximum of eight steps per trial, which comprises a maximum of 72 steps (8 steps x 3 trials x 3 beams).

*Moving sideways (MS)*

The children started with standing on a first box and holding a second box in their hands. After the start signal the children needed to place the second box alongside the first and step on it. Then the child needed to pick up the first box and place it again alongside the second one to step on it and so on as quickly as possible. Each child performed two trials of 20 seconds. The number of correct relocations of both trials summed up was scored as final raw outcome.

*Jumping sideways (JS)*

At this task the children needed to jump sideways over a wooden lath (60 cm x 4 cm x 2 cm) as many times as possible within 15 s. The number of correct jumps of two trials was summed and used as final raw outcome.

*Eye hand coordination (EHC)*

During the eye-hand coordination test the children needed to throw a tennis ball at a rectangle target (height 137 cm, width 152.5 cm; positioned at 1 m from the ground) on a flat wall at 1 meter distance with one hand and to catch the ball correctly with the other hand as many times as possible in 30 seconds. A modification on the original protocol was introduced for the children of the third and fourth grade classes (mEHC); they were allowed to use both hands for catching. This resulted in mEHC scores for all six- and seven-year olds, and for some of the eight-year olds. EHC of the eight-year-olds in grade five was assessed by the original EHC test. This resulted in two groups (i.e., mEHC and EHC) for the eight-year-olds. The best number of correct catches of two attempts was recorded as raw outcome score.

## Data collection

All children completed the assessment as part of their regular physical education classes in an indoor facility. The testers were physical education students in the final stage of their study or physical education teachers. All testers were well-trained to ensure that the test protocols were used in a standardised way. They first familiarized themselves with the test protocols and instructions and then they were given feedback during a training session by an expert. At all assessments an experienced tester supervised the measurements. The children’s sex and date of birth were provided by the school before the assessment.

### *Statistical analysis*

IBM SPSS Statistics 24 (IBM Corp., Armonk, New York, United States of America) was used for the statistical analyses. The test items' scores of WB, MS and JS were normally distributed. The distribution of the (m)EHC outcomes was positively skewed. Since transformation did not solve this non-normality, it was decided to check the normality of the model's residuals of bootstrapping in further analyses that included the (m)EHC outcomes to ensure the robustness of the analyses (Williams et al., 2013). Descriptive statistics of the assessment outcomes are presented by sex and age, separately.

First, univariate ANOVA analyses, including the raw test item scores one by one as dependent variables and sex and age as a fixed factor, were used to elucidate main and interaction effects of sex and age. Additional Sidak's post hoc tests were conducted in case of significant main effects of age. Second, for construct validity Pearson's correlation coefficients were calculated, while correcting for sex and age in line with the standardization sampled (Kiphard & Schilling, 1974; Faber et al., 2014) , to present the interrelationship between the raw test item outcomes in a correlation matrix. Additionally, bootstrapping (1000 samples) was performed to calculate 95% confidence intervals for the Pearson's correlation coefficients. Third, based on the available dataset, the raw scores of each test item were converted into norm values for each test item separately. Consecutively a movement quotient (MQ) was established by combining the norm values. The KTK's transformation methods described in the original manual were used for both the conversion of the raw scores into norm values per item and the conversion of the item norm values into a combined MQ. As such 100 and 15 points reflects the mean and the standard deviation of the norm population, respectively. Two calculations of the MQ were conducted: 1) the MQKTK-3 based on the results of the KTK-3 and 2) MQKTK-3 + EHC based on the KTK-3 and the Faber's test. All children were classified twice, based on the MQKTK-3 and based on MQKTK-3 + EHC, into one of the categories of FMS performance as suggested by Kiphard and Schilling (1974): severe disorder (≤ 70), moderate disorder (71-85), normal performance (86-115), good performance (116-130), high performance (≥ 131). The agreement between the classifications of MQKTK-3 and MQKTK-3 + EHC was evaluated using the percentage agreement and Cohen's kappa. Alpha was set at 0.05 for significance for all analyses.

## RESULTS

The results of the performance on the test battery per age group for boys and girls are shown in Table 2 and presented in Figure 1, respectively.

**Table 2.** Raw scores (mean ± SD) of the FMS assessment test items (T0) including univariate GLM analysis for effects of sex and age of six (n = 192), seven (n = 265), eight (n = 266), nine (n = 277), and ten (n = 121) year olds.

| | 6 | 7 | 8 | 9 | 10 | Sex | Age | Age x Sex |
|---|---|---|---|---|---|---|---|---|
| Boys | 25 ± 9.8 | 30 ± 10.8 | 37 ± 12.1 | 40 ± 11.8 | 39 ± 14.3 | F = 41.695 | F = 58.432 | F = 1.014 |
| Girls | 29 ± 10.5 | 37 ± 13.0 | 42 ± 14.3 | 46 ± 12.9 | 42 ± 13.9 | P < 0.001 | P < 0.001 | P = 0.399 |
| Total | 27 ± 10.3 | 34 ± 12.6 | 39 ± 13.4 | 43 ± 12.6 | 41 ± 14.0 | partial η2 = 0.037 | partial η2 = 0.175 | partial η2 = 0.004 |
| MS | 6 | 7 | 8 | 9 | 10 | Sex | Age | Age x Sex |
| Boys | 32 ± 7.3 | 38 ± 7.9 | 43 ± 7.8 | 46 ± 6.9 | 45 ± 6.8 | F = 0.047 | F = 114.844 | F = 0.510 |
| Girls | 33 ± 7.3 | 38 ± 7.3 | 42 ± 6.5 | 46 ± 6.6 | 46 ± 8.1 | P = 0.828 | P < 0.001 | P = 0.728 |
| Total | 33 ± 7.3 | 38 ± 7.6 | 43 ± 7.2 | 46 ± 6.8 | 45 ± 7.5 | partial η2 < 0.001 | partial η2 = 0.294 | partial η2 = 0.002 |
| JS | 6 | 7 | 8 | 9 | 10 | Sex | Age | Age x Sex |
| Boys | 39 ± 13.2 | 48 ± 14.4 | 58 ± 13.7 | 61 ± 11.6 | 67 ± 12.3 | F = 0.501 | F = 105.355 | F = 2.505 |
| Girls | 40 ± 12.7 | 49 ± 14.6 | 53 ± 14.0 | 62 ± 10.9 | 65 ± 14.9 | P = 0.479 | P < 0.001 | P = 0.041 |
| Total | 39 ± 12.9 | 49 ± 14.5 | 56 ± 14.0 | 61 ± 11.3 | 66 ± 14.0 | partial η2 = 0.001 | partial η2 = 0.292 | partial η2 = 0.010 |
| EHC[1] | 6 | 7 | 8 | 9 | 10 | Sex | Age | Age x Sex |
| Boys | - | - | 8 ± 6.1 | 11 ± 6.5 | 15 ± 6.4 | F = 15.827 | F = 29.021 | F = 1.094 |
| Girls | - | - | 7 ± 6.1 | 9 ± 6.1 | 12 ± 6.0 | P < 0.001 | P < 0.001 | P = 0.335 |
| Total | - | - | 8 ± 6.1 | 10 ± 6.5 | 13 ± 6.3 | partial η2 = 0.028 | partial η2 = 0.095 | partial η2 = 0.004 |
| mEHC[1] | 6 | 7 | 8 | 9 | 10 | Sex | Age | Age x Sex |
| Boys | 4 ± 4.7 | 8 ± 7.0 | 10 ± 7.2 | - | - | F = 9.169 | F = 39.267 | F = 1.983 |
| Girls | 3 ± 3.7 | 5 ± 5.1 | 9 ± 6.5 | - | - | P = 0.003 | P < 0.001 | P = 0.139 |
| Total | 3 ± 4.2 | 7 ± 6.2 | 9 ± 6.8 | - | - | partial η2 = 0.017 | partial η2 = 0.131 | partial η2 = 0.008 |

WB, walking backwards; MS, moving sideways; JS, jumping sideways; EHC, eye hand coordination; mEHC, modified eye hand coordination.
T0, first moment of testing. Post hoc analysis showed significant differences between all age groups for the four test items except between children of 8- and 10-years for WB and between children of 9- and 10-years for WB, MS and JS.
[1]Children in grade 3 and 4 (6, 7, and 8 year olds) performed the mEHC. Children in grade 5 and 6 (8, 9, and 10 year olds) did the EHC

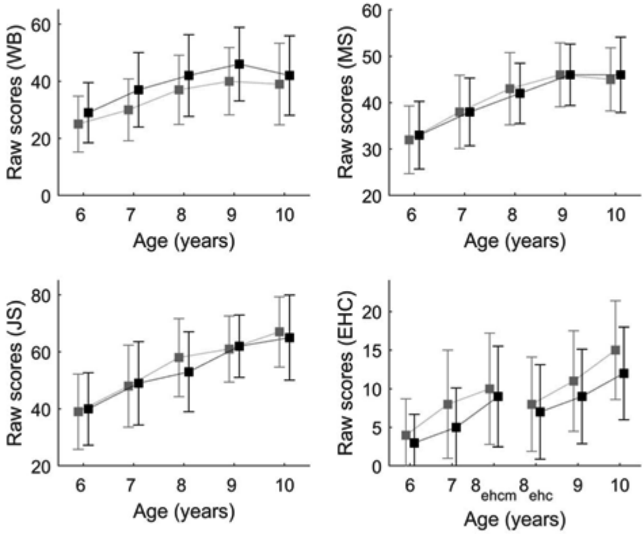


**Figure 1.** Raw scores of the four test items for boys (gray line) and girls (dark line) per age.

**Table 3.** Correlation matrix for interrelationship of the test items.

| | MS | JS | EHC | mEHC |
|---|---|---|---|---|
| WB | 0.40a | 0.42b | 0.17c | 0.21d |
| | (0.35-0.45) | (0.50-0.59) | (0.09-0.25) | (0.11-0.29) |
| MS | | 0.46e (0.42-0.51) | 0.14f | 0.27g |
| | | | (0.05-0.22) | (0.18-0.35) |
| JS | | | 0.32h | 0.28i |
| | | | (0.23-0.41) | (0.20-0.36) |

Data represent partial correlations coefficients (95% confidence intervals) correcting for sex and age.
WB, walking backwards; MS, moving sideways; JS, jumping sideways; EHC, eye hand coordination; mEHC, modified eye hand coordination.
adf = 1106, bdf = 1026, cdf = 555, ddf = 520, edf = 1029, fdf = 555, gdf = 523, hdf = 510, idf = 499.

## ***Sex and age differences***

The univariate GLM analyses (Table 2) showed significant effects for sex in WB and (m)EHC ($P < 0.05$) with small effect sizes (partial η2: WB 0.037, EHC 0.028, mEHC 0.017). At WB the girls outscored the boys and at (m)EHC the opposite was shown as the boys outscored the girls. A significant main effect of age was presented in all test items (P < 0.001) with effect sizes (partial η2) between 0.095 and 0.294. Post-hoc tests revealed that children of a certain age group scored significantly better than their 1-year younger peers on all test items (P < 0.05). Only at WB no significant difference was shown between the 10-year olds and their 8- or 9-year peers and at MS and JS between the 9-year olds and the 10-year olds. No interaction effects were found between sex and age (P > 0.05), except at JS (P = 0.041) with a small effect size (partial η2 = 0.010) (Cohen, 1992).

### *Interrelationship between test items*

The correlation matrix (Table 3) showed low to moderate positive associations between the test items with the 95% confidence intervals not including zero. The highest association was found between MS and JS (Pearson's r = 0.46; 95% confidence interval 0.42-0.51), the lowest between MS and EHC (Pearson's r = 0.14; 95% confidence interval 0.05-0.22).

**Table 4.** Agreement between the classification of motor abilities using the MQKTK-3 and MQKTK-3 + EHC.

| | | **MQKTK-3** | | | | | |
|---|---|---|---|---|---|---|---|
| | | severe motor disorder | moderate motor disorder | Normal | good | high | total |
| **MQKTK-3 + EHC** | Severe motor disorder | 19<br>(1,9%) | 7<br>(0.7%) | 0<br>(0%) | 0<br>(0%) | 0<br>(0%) | 26<br>(2,6%) |
| | moderate motor disorder | 6<br>(0.6%) | 70<br>(7.0%) | 44<br>(4.4%) | 0<br>(0%) | 0<br>(0%) | 120<br>(12.0%) |
| | normal | 0<br>(0%) | 32<br>(3.2%) | 628<br>(62.5%) | 43<br>(4.3%) | 0<br>(0%) | 703<br>(70.0%) |
| | good | 0<br>(0%) | 0<br>(0%) | 41<br>(4.1%) | 85<br>(8.5%) | 7<br>(0.7%) | 133<br>(13.2%) |
| | high | 0<br>(0%) | 0<br>(0%) | 0<br>(0%) | 13<br>(1.3%) | 9<br>0.9%) | 22<br>(2.2%) |
| | Total | 25<br>(2.5%) | 109<br>(10.9%) | 713<br>(71.0%) | 141<br>(14.0%) | 16<br>(1.6%) | 1004<br>(100%) |

Data represent the number of children classified in a certain classification and percentage of the total. Percentage agreement between MQ3 and MQ4 is 80.8% with a Cohen's kappa of 0.59 (p <0.001). MQ = movement quotient; KTK-3 includes walking backwards, moving sideways and jumping sideways; KTK-3 + EHC includes walking backwards, moving sideways, jumping sideways and eye hand coordination (modified).

### *Agreement between MQKTK-3 and MQKTK-3 + EHC*

The children who completed all test items were included to obtain the MQKTK-3 and MQKTK-3 + EHC and were classified into the fundamental movement skill categories severe performance (≤ 70), moderate performance (71-85), normal performance (86-115), good performance (116-130) and high performance (≥ 131). There was an agreement between the classification based on the MQKTK-3 and MQKTK-3 + EHC in 811 of the 1004 children included, which corresponds to 80.8% agreement with a Cohen's kappa valuing 0.59 ($P < 0.001$) (Table 4). When there was no agreement, the difference was one category only; 10.0% of the children were classified in a higher category based on the MQKTK-3 and 9.2% of the children were classified in a higher category by the MQKTK-3 + EHC.

## DISCUSSION

This study evaluated the combination of the KTK-3 and Faber's eye hand coordination test, the so-called KTK-3 + EHC, to assess fundamental movement skills in primary school children within the age-span of six to ten years. The results indicate that the KTK-3 + EHC is generally able to cover a broad performance spectrum. Moreover, the test items appear to adequately cover different aspects of the fundamental movement skills as the item's present only low to moderate interrelationship. The low associations between the (m)EHC test item and the KTK-3 items, suggests the (m)EHC test item measures another aspect than the other three items do. The (m)EHC test complement the KTK-3 assessing locomotor and balance skills with a new aspect, i.e. object control, to measure fundamental movement skills. Also, the differences between the classifications of the children when using the MQKTK-3 or the MQKTK-3 + EHC supports that the (m)EHC test item is of adding new insights on a child's motor performance. Finally, the four tests appear easily applicable and do not place burden on professionals' time; in this study 25 children were tested within 45 minutes with four test leaders. Consequently, the KTK-3 + EHC seems to have good prospects to measure fundamental movement skills in applied settings.

To our understanding, adding the Faber's test to the MQKTK-3 enriches the FMS measurement. The original KTK was recommended by its quick screening ability, and for its reliable, accuracy and standardization (Cools et al., 2009). It was also favoured because of the capacity to measure locomotor and balance skills of all children, even those with well-developed skills (Vandorpe et al., 2011; Catuzzo et al., 2015; Ahnert & Schneider, 2007). The use of several test items to determine a child motor competence is required to decrease the influence of one-time testing (Kiphardt & Schilling, 1974). With an object control skills measurement included the KTK-3 + EHC test measures a broader range of the FMS of children as defined by our colleagues (Gallahue et al., 2012). This study showed that the EHC test has lower associations than the other three have indicating different aspects of FMS measured. Including the (m)EHC test resulted in around 20% of the children being classified in another category. Provided the importance of object control for motor behaviour in daily life and specifically for performance in ball and racket sports (Butterfield et al., 2012), adding the (m)EHC test item to the KTK short form to measure fundamental movement skills is recommended.

The ability to cover a broad performance spectrum is confirmed in this study by the fact that no bottom and ceiling effects were present in the data of the subsamples. Children with already high FMS competence are challenged by the test even as that the four tests items are applicable for those children with weak competences. For primary education settings this is highly relevant as variance in competences between children in this age group are high. Most other tests are developed to identify children with motor problems (Vandorpe et al., 2011), and are not able to distinguish between better movers and not applicable to analyse intervention studies due to ceiling effects (Cools et al., 2009). Only the EHC showed a bottom effect in the 6 and 7-year-olds in both sexes. This test item seemed to be rather difficult to perform for most of the younger children. Therefore, a modified version of the original test in which catching was allowed with both hands was implemented. Nevertheless, the mEHC, like the EHC and the KTK-3 items, was able to discriminate between the performances of the included age groups and the bottom effect seemed to have a negligible effect on the distribution of the MQKTK-3 + EHC outcomes.

In addition of the absence of ceiling effects, the increase of the performance level per age-group represent the capacity of the KTK-3 + EHC to measure within the full performance spectrum. In line with the results of other studies (Vandorpe et al., 2011; Ahnert & Schneider, 2007; Fransen, 2014), this study revealed that there is a significant difference in fundamental movement skill performance with increasing age. This demonstrates that it is necessary to make use of age-related reference values for the four subtests. In contrary to the results of other studies, the ten-year-olds did not outperform the eight- and nine-year-olds on WB, and the nine-year-olds on SP and JS. A possible explanation is the inclusion of the 10-year-olds. For practical reasons, only children from grade 3 through 6 were measured. As a result, we included only the relatively younger 10 years-olds (mean age in this study was 10.38), which do not fully represent ten-year olds in general. In a next study more 10-year-olds, for example those in grade 7, should be assessed to have a representative sample for this age group. It was shown before (Fransen et al., 2014), that with increasing age, the improvement in score at the three subtests of the KTK diminishes, especially at WB. This might also provide an explanation for the results found in this study.

Besides the use of age-related reference values, it is recommended to use different norms for both sexes at the (m)EHC test and the WB test. Similar to the results found by our colleagues (Vandorpe et al., 2011) in this study girls scored higher on the WB test. On the EHC test boys outperformed girls, which is in line with our colleagues (Faber et al., 2017). The differences between boys and girls before puberty are probably not explained by differences in the amount of physical activity and physical fitness (Cherney, 2006). A more reasonable explanation is the different preference of activities of boys and girls. Girls practice outside more activities related to gymnastics (e.g., rope jumping, bar), whereas boys prefer to play with a ball (Thomas & Thomas, 1988). Sex related references values are considered to give a better evaluation of the fundamental movement skills performance level of an individual child compared to his / her peers.

Some limitations of this study need to be acknowledged. First, it is noteworthy that the four subtests do not measure all skills (e.g., walking, dodging) linked to FMS. It was decided to develop a set of four tests that measure all three different FMS skills as described by our colleagues (Gallahue et al., 2012). With these four subtests the broad performance spectrum of FMS performance of 25 to 30 children can be assessed within limited time. Measuring more items could increase the validity but will be too time consuming (Cools et al., 2009). Second, to generalize the results of this study more measurements are needed. In contrary to about 50% of the Dutch children, children in this study have at least once a week PE from a specialist PE teacher. Also, in this study only regular primary schools participated. More measurements are needed to set norms, with its limitations as described before, and evaluate the influence of age and sex, also in older age groups (i.e., 11- and 12-year olds). Finally, it needs to be acknowledged that children's development of fundamental movement skill performance is not a linear process and the variability of FMS performance is high (Clark, 2007; Fransen, 2014). Our colleagues (Logan et al., 2017) stated the importance to make use of both product and process-oriented (i.e., a focus on the quality of movement) assessment tools to provide a more comprehensive view of FMS performance. To our understanding, a comprehensive view of FMS performance can be obtained by the KTK-3 + EHC instrument and preferably in combination with more qualitative assessments made by the professional who observe children week in week out.

To conclude, this study focused on the evaluation of the KTK-3 + EHC test to assess six- to ten-year olds FMS performance in a simple and objective way. The feasibility of the instrument is high and to our understanding the KTK-3 + EHC test could be of great value for professionals working with children in this age group. It gives them a tool with which they can objectively assess children FMS performance which provide opportunities to better meet children's individual developmental needs and evaluate the effectiveness of their own practices.

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### *Author contributions statement*

SP, IF, MN, and JP contributed conception and design of the study; SP, MN and RK acquired the data; MN and RK organized the database; IF and JP performed the statistical analysis; SP and IF wrote the first draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

### *Conflict of interest statement*

The authors did not have any conflict of interest with the submission of this manuscript.

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