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The comparative analysis of postural and biomechanical parameters of preschool teachers pre- and post-intervention within the ErgoKiTa study

Eva-Maria Burford[a], Rolf Ellegast[a], Britta Weber[a], Manuela Brehmen[b], David Groneberg[b], Andrea Sinn-Behrendt[c] and Ralph Bruder[c]

[a]Institute for Occupational Safety and Health of the German Social Accident Insurance, Sankt Augustin, Germany; [b]Institute of Occupational, Social and Environmental Medicine, Goethe University of Frankfurt, Frankfurt am Main, Germany; [c]Institute of Ergonomics, Technical University of Darmstadt, Darmstadt, Germany

ABSTRACT
The ErgoKiTa study aimed to determine the musculoskeletal strain of preschool teachers and to identify and evaluate suitable prevention measures to reduce this strain. A comprehensive work analysis using objective and subjective methods was performed to determine the present work situation in preschools in Germany, and the results were used to derive suitable intervention measures. The musculoskeletal strain was determined by means of a comprehensive analysis of postures, forces and movements using the CUELA system and calculated as cumulative shift workloads. The intervention measures were evaluated in a pre- and post-intervention assessment for 12 participants. Significant alterations in the duration of postures were determined, specifically for the daily duration of knee-straining postures as well as the degree of trunk flexion between 60° and 90°, which were reduced from 8.4 to 3.1% and from 3.7 to 2.4%, respectively, following the intervention.

Practitioner Summary: Research has shown that preschool teachers are at risk of developing musculoskeletal disorders. The effects of a situation-orientated and behaviour-orientated intervention approach were assessed with regard to awkward working postures. Significant alterations in the duration of postures following the intervention were found, specifically for knee-straining postures.

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Musculoskeletal strain; postural analysis; preschool teachers; intervention

1. Introduction

Musculoskeletal disorders (MSDs), which include inflammatory and degenerative disorders that affect the low back, neck, upper and lower limbs, are among the leading causes of occupational injuries (Punnett and Wegman 2004) and have a considerable socio-economic impact (Lambeek et al. 2011; Maniadakis and Gray 2000; Vermeulen et al. 2013). Epidemiological and experimental studies have shown that the physical work features that are recurrently cited as MSD risk factors include rapid work pace, repetitive motion patterns, insufficient recovery time, heavy lifting and awkward body postures (Ariëns et al. 2000; Punnett and Wegman 2004). A combination of these factors as well as unfavourable features of the psychosocial environment such as a lack of control over one's individual work and high demands are further considered as risk factors (Punnett and Wegman 2004; Widanarko et al. 2014). Of these risk factors, manual lifting of loads, awkward body postures and the potential combination of these factors with psychosocial stress elements are all present in the teaching profession and more so in the preschool environment (Erick and Smith 2011).

Preschool teachers are required to perform a variety of tasks that include teaching and supervision, as well as feeding and hygiene care tasks (Grant, Habes, and Tepper 1995). These tasks result in various postures being adopted throughout the work day that include walking, stooping, lifting, squatting, prolonged standing and kneeling (Grant, Habes, and Tepper 1995; Gratz et al. 2002; King et al. 1996) with the resulting workload being described from a metabolic perspective as light activity (Grant, Habes, and Tepper 1995). As the facilities are usually designed to be height-appropriate for children, preschool teachers adopt awkward body postures in order to perform their work tasks (King, Gratz, and Kleiner 2006) such as a 'head down' posture (Chiu and Lam 2007) or bending down at the waist adopting a posture of sustained trunk flexion (Erick and Smith 2011), as well as sustained periods of stooping and

CONTACT Rolf Ellegast Rolf.Ellegast@dguv.de

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knee-straining postures such as squatting and kneeling to be at the level of the child (Grant, Habes, and Tepper 1995). Several studies (Coggon et al. 2000; Cooper et al. 1994) have shown that even percentages as low as 6% (Cooper et al. 1994) of the work shift spent in knee-straining postures can result in elevated risks of MSDs, specifically knee osteoarthritis. It is these non-neutral postures that are considered risk factors for developing MSDs (Grant, Habes, and Tepper 1995; Punnett and Wegman 2004).

Only a handful of internationally published studies, predominantly conducted in Japan, Sweden and the USA (Brulin et al. 1998; Grant, Habes, and Tepper 1995; Ono et al. 2002), have investigated MSDs in preschool teachers (Brulin et al. 1998; Cardoso et al. 2009; Grant, Habes, and Tepper 1995; Gratz and Claffey 1996; King et al. 1996; Labaj et al. 2016; Nagira et al. 1981; Ono et al. 2002; Tsuboi et al. 2002) and research suggests that teaching may be a high-risk occupation for MSDs (Erick and Smith 2011). A systematic review by Erick and Smith (2011) indicates that the prevalence rate of MSDs in teachers and preschool teachers ranges between 40% and 95%. An increased prevalence of neck, shoulder, arm and low back pain in addition to lower extremity MSDs has been reported (Grant, Habes, and Tepper 1995). Despite this, there is a limited literature regarding this topic and even less attention has been paid to how to reduce MSDs in the preschool environment by addressing the potential work factors that influence the likelihood of developing MSDs. Furthermore, only limited research has investigated the stress and strain of occupations in this field (Kusma et al. 2011) and, as highlighted in the study by Labaj et al. (2016), even fewer studies have focused on the objective musculoskeletal workload. Existing means to reduce the physical strain experienced as a result of work-related factors and improve the working posture in this occupation have yet to be evaluated and validated. In addition to the physical stress levels, various studies indicate that preschool teachers are also exposed to high psychological stress levels (Eysel-Gosepath et al. 2010; Rudow 2004). As complaints regarding excessive stress in the preschool workplace are being increasingly reported (Darius et al. 2013), this is a current and key topic that will only become exacerbated with time as the number of children entering preschool increases (Darius et al. 2013; Grant, Habes, and Tepper 1995).

Based on the above highlighted deficits, the ErgoKiTa (ErgoKiTa: Ergonomic design of workplaces in preschools) study was initiated to ascertain the current state of knowledge available on the musculoskeletal strain of preschool teachers; to determine the current situational workload that preschool teachers in Germany are exposed to; and to provide evaluated prevention measures. The research question from the project that is addressed in this paper is: 'Would a combination of situation-orientated and behaviour-orientated measures affect the working posture of preschool teachers and reduce the duration of awkward working postures adopted?' This research hypothesised that based on the supplied intervention, a basic intervention package of different furniture options and individualised awareness sessions described later in the method, musculoskeletal strain indicators would be reduced when assessed following the intervention. The musculoskeletal strain indicators hypothesised to be reduced for the projected 8-h shift include: knee flexion, trunk flexion, trunk rotation and moments at the lumbar spine (L5/S1 joint).

2. Method

The ErgoKiTa study adopted a sequential mixed methods approach to determine and evaluate potential intervention means. In an initial phase, current work structure parameters were determined through questionnaires distributed to preschools in three German states, namely North-Rhine/Westphalia, Rhineland-Palatinate and Hesse, with 262 preschools responding. In the second phase of the study, drawing on the results of the questionnaire distributed in the initial phase, 24 preschools were selected for further analysis. The 24 preschools were selected based on the following criteria:

- children below the age of three attended the preschool,
- at least 80% of the children attended the preschool for at least 5 h a day,
- the preschool consisted of at least two classes/groups of children.

These criteria were determined by the questionnaire results from all 262 preschools and were selected as they were consistent elements that could not be readily altered or modified. This allowed for a more accurate comparison of preschools within similar parameters, such as the size of the preschool and the number and age of children attending the preschool.

Based on questionnaires, and follow-up site inspections with standardised checklists, the 24 preschools were classified as having a low, intermediate or high intervention need (Sinn-Behrendt et al. 2013). The elements upon which the classification was based included the facilities and furnishings, the size of the rooms, the training and development of the staff, the work climate and the pedagogical concept (Sinn-Behrendt et al. 2013). As no previous literature recommendations for the classification of preschools was available, these three categories were defined to suggest a priority for the intervention need following assessment. Nine preschools from the initial 24 were selected to be included in the intervention development phase of the study. In this second phase, various psychosocial and physical risk factors, such as working posture and work environment aspects, were assessed both qualitatively and quantitatively for specific tasks and projected 8-h shift values were calculated for the nine preschools selected. Based on the findings, suitable prevention measures were derived and implemented in six of the nine preschools that were classified as having an intermediate or high intervention need. The effect of the intervention was then assessed using the same method applied in the pre-intervention assessment. A diagrammatic representation of the phases adopted in this research project is depicted in Figure 1. The focus of this paper was to compare the objective results of the postural and biomechanical parameters for preschool teachers assessed prior to and following the intervention phase of this study. More detailed information pertaining to the different phases of this project are available in the online report (Sinn-Behrendt et al. 2015).

2.1. Research design

The research employed a quasi-experimental design with repeated measures to conduct a before-after comparison, with the musculoskeletal workload of preschool teachers being assessed *in situ* both prior to and following the intervention. The intent of this study was to pragmatically assess the potential effect of the intervention plan consisting of both situation-orientated and behaviour-orientated measures on the posture and workload of the preschool teachers. Both assessments occurred approximately at the same time of year in 2012 and 2013, one year apart to reduce the effect of season on postures and workloads of the teachers.

2.2. Participants

From the 262 preschools that completed the general questionnaire, 24 preschools were selected for further analyses (Figure 1). Nine preschools from the initial 24 were selected, based on follow-up site inspections and standardised checklists, to be included in the intervention development phase of the study. The nine preschools that were included were representative of the majority of the preschools from the three German states involved in the study. These preschools were selected so that one preschool per classification category for each state was included.

The nine preschools were involved in the workload analyses during the pre-intervention phase, and these data were used to develop the intervention measures. In the post-intervention phase, the six preschools that had been classified as having an intermediate or high intervention need were analysed. The results and data from the six preschools that participated in both the pre- and post-intervention phases were compared and these results are included in this article. For the pre- and post-intervention assessment, in each preschool the musculoskeletal workload of two of the preschool teachers from the preschools' teaching body were assessed (n = 12). Of the 12 participants that were assessed, all were female and employed as a preschool teacher. The mean length of employment as a teacher of the 12 participants assessed was 9.2 years (±7.8 years) with the mean length of employment in the current preschool where the assessment took place was 6.6 years (±7.4 years). The mean number of children supervised per day by the participants assessed was 19 (±4) and the children were between the ages of one and five. The participant characteristics are described in Table 1.

2.3. Instrumentation: kinematics and heart rate

The musculoskeletal workload of the teachers was assessed using the ambulatory CUELA system ('Computer-assisted recording and long-term analysis of musculoskeletal loads'). This 10 mobile sensor system consists of accelerometers (Analog Devices ADXL 103/203) and

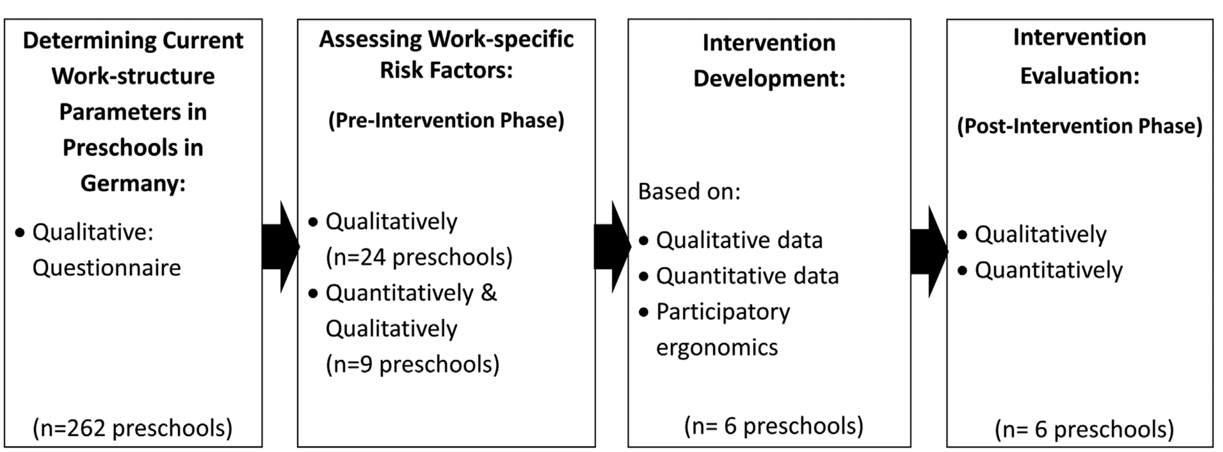

Figure 1. The sequential mixed methods approach adopted to develop intervention measures for the preschool environment.

Table 1. Participant characteristics of the 12 preschool teachers that took part in the work assessment in the pre- and post-intervention phase.

	Pre-intervention		Post-intervention	
	Mean	SD	Mean	SD
Height (cm)	168.5	6.1	168.6	6.4
Body weight (kg)	72.4	14.7	73.1	15.8
Age (years)	34.1	10.1	35.8	10.2
BMI (kg/m^2)	25.5	5.0	25.7	5.4

gyroscopes (mu Rata ENC-03R) (Ellegast, Hermanns, and Schiefer 2009; Ellegast and Kupfer 2000) that allows for the continuous and instantaneous measurement of body postures adopted, and movements and forces generated. The postural data recorded included the kinematic data of the trunk, and lower and upper limbs (Ellegast et al. 2006; Glitsch et al. 2007). The estimation of trunk orientation used in this study was very similar to the use of a hybrid system and its assessment in a previous laboratory study (Plamondon et al. 2007). The accuracy of this type of system and the employed sensor fusion algorithm in reference to an optical motion capturing system is described in the study by Plamondon et al. (2007). For the listed body components, the following postures and corresponding degrees of freedom were determined:

- Thoracic spine (1 sensor): sagittal and lateral inclination at the third thoracic vertebra
- Lumbar spine (1 sensor): sagittal and lateral inclination at the fifth lumbar vertebrae
- Upper arm right/left (total: 2 sensors): spatial orientation
- Lower arm right/left (total: 2 sensors): spatial orientation
- Thigh right/left (total: 2 sensors): spatial orientation
- Lower leg right/left (total: 2 sensors): spatial orientation

Trunk flexion in this study has been defined as the average trunk inclination angle, as this mostly corresponds with the definition of the trunk flexion angle as defined by the European Standard EN 1005-4 (CEN 2005). The trunk inclination angle was determined from the averaged T3 and L5 sagittal inclination angles. Additional trunk movements such as the torsion of the upper body were recorded by sensors located on the upper and lower body, joined by a metal shaft that was connected to a magnetic field sensor (Vert-X 12, Contelec). Through the analysis of the ground reaction forces using pressure sole-insert sensors (Paromed) and a biomechanical model (Ellegast, Kupfer, and Reinert 1997), the lifting of loads was assessed. All data were stored on a flash memory card in the participant-bound data logger at a sampling rate of 50 Hz. The participant was filmed for the entire data capturing session to allow for the assignment of specific tasks, as defined in the study by Kusma et al. (2011), in the data preparation phase. In Figure 2, the CUELA system specifically adapted for this occupational group is depicted.

All body angles were initialised at the beginning of the data capturing session in an upright standing posture, which assisted in eliminating individual angle offsets. As a result of this processing, movement artefacts are less than ±1° in low vibrational environments, and despite a postural angle error of ±2.5° after 2 h, this measurement

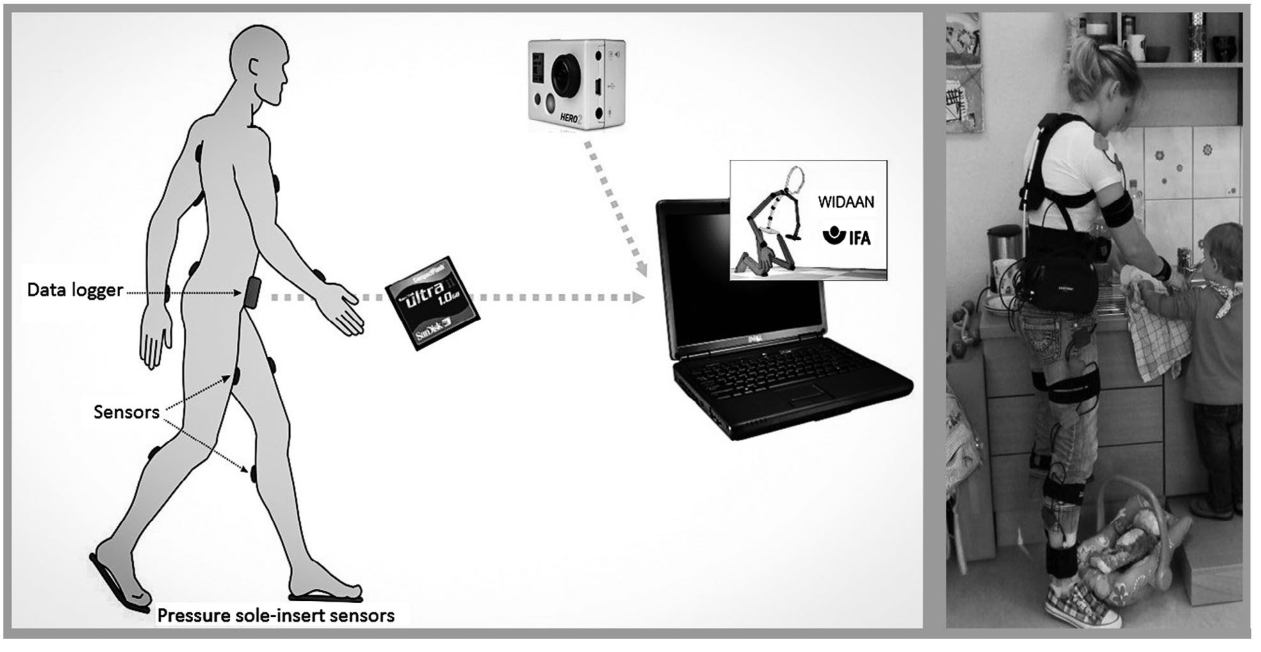

Figure 2. Set up of the CUELA system used to assess *in situ* the workload experienced by preschool teachers.

system is more reliable and impartial than observational methods (Hermanns et al. 2008).

2.4. Procedure

2.4.1. Pre- and post-intervention analysis

In both the pre- and post-intervention phases, the same two teachers from the six preschools that were classified as having an intermediate or high intervention need were assessed. The post-intervention assessment took place two months following the introduction of the new furniture from the intervention package and the individualised awareness session. An identical protocol and procedure was used for both the pre- and post-intervention assessments.

The ambulatory CUELA system (Ellegast, Hermanns, and Schiefer 2010) was used to analyse the musculoskeletal workload, for each teacher performing her usual duties, for approximately 4 h during a normal work day on two separate days. At the start of the working day, participants were asked their work routine for an 8-h shift. This information was used to determine the times of the assessments for the two data capturing days and provided the work schedule to calculate the shift values, as it was essential that each task in the work schedule was captured at least once with the CUELA system during the two days. Following this, participants were fitted with the CUELA system. All sensors were attached and secured on top of the participants' clothing (Ellegast, Hermanns, and Schiefer 2009) using Kintex bands and an online-check and calibration of the CUELA system was conducted at the beginning of the data capturing session. For calibration, under guidance of the researcher, participants were required to adopt a reference posture that consisted of standing upright, arms at the side and legs together. Approximate commencement and end times of the different tasks were recorded. The participant was filmed for the entire data capturing session to allow for the assignment of specific tasks, as defined in the study by Kusma et al. (2011).

2.4.2. Intervention

The intervention was implemented in the six preschools that were classified as having an intermediate or high intervention need. The intervention measures were derived from the objective data as well as through the use of participatory ergonomics as this has been shown as an effective means for reducing the exposure to biomechanical and psychosocial risk factors (Jensen 1997; Pehkonen et al. 2009; Tompa, Dolinschi, and Laing 2009).

Based on the participatory ergonomics framework by Haines and Wilson (1998) and Haines et al. (2002), the intervention had aspects from all nine dimensions. The mix of participants consisted of preschool teachers, management, external advisors from various institutes with specialisation in ergonomics and occupational medicine, as well as representatives of the social accident insurance institutions of the involved states. The requirement for participation was voluntary, the involvement was full and direct and the decision-making was based on group consultation. The remit included problem identification and solution development, with the focus on tools and equipment. The level of influence was at a work group level but for numerous preschools. The permanence was to be ongoing as the implemented intervention remained in place following the end of the project. The role of the ergonomic specialists was to initiate and guide the process, act as a team member and train members.

Participatory ergonomics was applied throughout the project and consisted of workshops and training. The workshops were conducted with the participants, project team and stakeholders at each phase of the project to discuss the problem, identify possible solutions, select the furniture that formed part of the intervention, implementation of the intervention and finally the evaluation of the intervention. The intervention incorporated both situation-orientated and behaviour-orientated prevention measures. The behaviour-orientated prevention measure consisted of a 90-min individualised awareness session for the participants and was developed through the analysis of the biomechanical, postural and video data, in order to highlight awkward postures adopted during the working day. The data were analysed using a top-down approach. The calculated shift data were used to quantify the duration of awkward postures adopted throughout a work day, and following this a task analysis was used to identify potential sites and tasks that required attention during the intervention. In the final step, individual scenarios of awkward postures were selected from the video data. During the awareness sessions, using a problem-solving approach, participants were shown working situations where awkward postures occurred and discussions were initiated on how to improve and to potentially perform the task differently in a less awkward posture while incorporating the newly acquired furniture. This allowed for the participants to draw on previous experience (Tompa, Dolinschi, and Natale 2013) and potentially think of ways themselves of conducting a task that would require less awkward body postures.

The situation-orientated measures consisted of a basic furniture package. The list of items in the basic furniture package was compiled by the project team using the results from the CUELA analysis, the questionnaires and the workshops conducted during the data capturing phase with the preschool staff. The intervention package was then individually tailored to the six selected preschools in the study cohort through additional workshops conducted with the educational staff. The furniture package consisted of different seating options, table options, children's beds and diaper-changing tables. The seating options consisted of adult chairs that could be lowered to 37 cm off the ground to allow the teacher to sit comfortably at children tables, adult chairs with wheels and seats that panned, ergonomic cushions for floor work and children seats that could be elevated to the height of an adult table. The table options consisted of models of different heights with wheels and no frames beneath the desktop in order to increase the legroom for the teacher. The children's beds consisted of lighter models than those available in the preschools at the time of the pre-intervention assessment. The diaper-changing tables had steps so children would not need to be lifted on to the table. Two 'before' and 'after' examples with regard to the implemented furniture packages have been included in Figures 3 and 4. Following the introduction of the new furniture and the awareness session, approximately a two-month period of no interference was observed.

2.5. Data processing and evaluation

The data were processed using the CUELA software, which allowed for the synchronisation of the video and CUELA data in addition to the assignment of intervals for specific

Figure 3. The preschool teacher's posture in the pre-intervention phase (A) and post-intervention phase (B) for the task of assisting children getting dressed.

Figure 4. The diaper table used in the pre-intervention phase (A) and the one used in the post-intervention phase (B) that through the new design reduced the likelihood of lifting the child onto the table.

tasks. For the body posture assessment, the body angles were classified according to the categories as described by ISO 11226 and EN 1005-4 (CEN 2005). The CUELA posture code classified posture into the categories of 'standing', 'walking/active', 'seated postures', 'knee-straining postures' and 'other'. Knee-straining postures identified by this code are postures that have been recognised as risk factors for knee pathologies and include squatting, supported and unsupported kneeling, sitting on heels and crawling (BMGS 2005).

The data were analysed as duration percentages of unfavourable postures and used in biomechanical model calculations (Ellegast 1998; Glitsch et al. 2007) to determine the quantity of the moment vector at L5/S1. These moment vectors were classified according to categories by Tichauer (1975) as either low risk (less than 40 Nm), medium risk (between 40 Nm and 85 Nm), moderate-to-high risk (between 85 Nm and 135 Nm) and high-risk classification (greater than 135 Nm). The postural data and durations for the different tasks were determined by segmenting the 4-h data into the individual tasks observed. The individual task segments were then used in addition to the documented schedule for a characteristic 8-h work day and calculated as a shift value for the percentages of body angles for each assessment day using the method verified by Ditchen et al. (2014).

2.6. Statistics

The percentages in the defined categories showed in both the Kolmogorov–Smirnov Test and the Histograms as well as in QQ-Plots that the distribution of the data was not that of a normal distribution and hence to test the effect of the intervention, non-parametric statistical hypothesis tests were selected. The dependent variables for the pre-intervention and post-intervention phases were assessed using the Wilcoxon signed-rank test for paired samples. SPSS Statistics (Version 20) was used for the statistical analysis and an asymmetric two tailed test was conducted on all variables assessed using a 95% confidence interval.

3. Results

The intervention was evaluated by determining if a statistically significant alteration in the duration of postures, more specifically a reduction in the duration of awkward postures as calculated by the shift values, occurred between the initial and second data capturing phase. All results are presented as the duration percentage of an 8-h shift for the various posture categories.

The CUELA posture classifications indicated significant changes in the duration of the different postures following the intervention. The mean and standard deviation of the percentage of the durations for different postures as defined by the CUELA postural code for the two data capturing phases is presented in Table 2. These results show a significant alteration in the percentages of the adopted body postures for seated and knee-straining postures. Knee-straining postures identified by this code consist of squatting, supported and unsupported kneeling, sitting on heels and crawling. The duration of knee-straining postures was significantly reduced from 8.4% (±9.0%) to 3.1% (±4.5%) of the shift, with a *p*-value of 0.023. The duration of seated postures following the intervention increased from 28.5% (±8.2%) to 40.7% (±8.9%) (*p*-value: 0.008). No significant changes in the duration percentage for the postural codes 'standing', 'walking/active' or 'other' were determined. Postures included in the codes 'walking/active' and 'other' consisted of walking, dancing, and running, and any activities that could not be categorised into the remaining codes, respectively. The implications of these results will be further addressed in the discussion.

The trunk posture results indicate that duration of trunk flexion greater than 60° and less than 90°, which is classified as a moderate risk (ISO 11226), following the intervention was significantly reduced from 3.7% (±2.9%) to 2.4% (±1.4%) of an 8-h shift (*p*-value: 0.034). Trunk flexion that fell within the category of less than 0° namely trunk extension, increased from 5.4% (±5.3%) to 10.8% (±11.1%) of an 8-h shift, but at a *p*-value of 0.05, this increase was not significant. For trunk rotation, significant alterations occurred for all reach classifications except for the positions greater than 20° to the right. The duration of trunk rotation greater than 20° (to the left), classified as a high-risk posture (ISO 11226), increased significantly from 1.4% (±1.2%) to 4.7% (±5.5%), with a *p*-value of 0.023. For the duration of trunk rotation greater than 10° (to the left), which is classified as a moderate-risk posture (ISO 11226), a significant increase from 8.1% (±4.1%) to 15.6% (±8.6%) occurred, with a *p*-value

Table 2. *P*-value, mean and standard deviation (SD) of the percentage of the calculated shift for 'Standing', 'Seated', 'Knee-straining', 'Walking/Active' and 'Other' postures as classified by the CUELA postural code for the main adopted postures.

Parameter: CUELA postural code	*p*-Value	Pre-intervention		Post-intervention	
		Mean (%)	SD (%)	Mean (%)	SD (%)
'Standing' postures	0.084	44.3	8.0	37.9	6.7
'Seated' postures	0.008	28.5	8.2	40.7	8.9
'Knee-straining' postures	0.023	8.4	9.0	3.1	4.5
'Walking/Active' postures	0.530	18.5	4.1	17.8	4.2
'Other' postures	0.893	0.4	1.2	0.4	1.5

Table 3. *P*-value, mean and standard deviation (SD) of the percentage of the calculated shift for the trunk and knee postures as classified by the EN 1005-4.

Parameter: Percentage of the work shift for different postures classified according to degree		*p*-Value	Pre-intervention		Post-intervention	
			Mean (%)	SD (%)	Mean (%)	SD (%)
Trunk flexion	<0°	0.050	5.4	5.3	10.8	11.1
	0° to >20°	0.583	69.6	10.4	68.1	10.3
	20° to >40°	0.480	15.5	8.2	14.2	8.0
	40° to >60°	0.071	5.5	2.5	4.3	1.6
	60° to >90°	0.034	3.7	2.9	2.4	1.4
	>90°	0.213	0.3	0.3	0.3	0.3
Trunk rotation[a]	≤−20°	0.023	1.4	1.2	4.7	5.5
	−20° to >−10°	0.019	8.1	4.1	15.6	8.6
	−10° to >10°	0.041	80.5	5.1	74.0	10.4
	10° to >20°	0.034	8.5	5.1	4.8	3.4
	>20°	0.084	1.5	1.2	0.9	1.2
Knee position during seated postures	Not seated	0.008	71.1	8.5	59.3	8.9
	0° to >45°	0.710	1.5	1.7	3.4	5.4
	45° to >90°	0.050	4.5	4.7	9.1	5.7
	90° to >100°	0.023	2.2	1.5	5.3	3.9
	100° to >110°	0.136	3.9	3.8	5.4	2.1
	110° to >120°	0.272	4.6	3.1	5.0	2.0
	120° to >130°	0.092	3.4	2.0	4.7	2.5
	>130°	0.754	8.8	4.1	7.7	4.9

[a]Trunk Rotation: negative values indicate trunk rotation to the left side, positive values indicate trunk rotation to the right.

of 0.019. Trunk rotation to the right between 10° and 20°, significantly reduced in duration from 8.5% (±5.1%) to 4.8% (±3.4%), with a *p*-value of 0.034. With regard to trunk rotation classified as neutral, between 10° to the left and right (ISO 11226), a significant reduction in duration from 80.5% (±5.1%) to 74.0% (±10.4%) occurred, with a *p*-value of 0.041. These results are presented in Table 3.

Similarly, as shown in Table 3, knee postures also showed significant differences when the pre- and post-intervention assessments were compared. The percentage of the working day in a non-seated posture significantly reduced from 71.1% (±8.5%) to 59.3% (±8.9%), with a *p*-value of 0.008, which corresponds to the CUELA posture code results that showed an increase in the percentage of time in a seated posture. The percentage of time the knee joint was between 45° and 90°, classified as a neutral-risk position (EN 1005-4), showed an increase from 3.5% (±4.4%) to 8.8% (±5.4%) in the descriptive results but at a *p*-value of 0.05, this increase was not significant. Additionally, the duration of the working day in which the knee posture was between 90° and 100°, significantly increased from 2.2% (±1.5%) to 5.3% (±3.9%), at a *p*-value of 0.023. No significant changes in the duration of the knee postures occurred for any interval ranges above 100°.

For the calculated moments at L5/S1, a significant change in the duration percentage occurred only in the category of moments above 135 Nm. These results are presented in Table 4. The duration percentage of moments greater than 135 Nm increased from 0.06% (±0.09%) to 0.66% (±0.79%), at a *p*-value of 0.014.

Table 4. *P*-value, mean and standard deviation (SD) of the percentage of the calculated shifts for moments at the L5/S1 joint as classified by Tichauer (1975).

Parameter: Moment (at L5/S1)	*p*-Value	Pre-intervention		Post-intervention	
		Mean (%)	SD (%)	Mean (%)	SD (%)
<40 Nm	0.875	59.38	20.60	60.62	18.51
40–85 Nm	0.754	37.73	18.60	35.66	16.18
85–135 Nm	0.530	2.83	3.99	3.06	2.47
≥135 Nm	0.014	0.06	0.09	0.66	0.79

4. Discussion

As physical job features are considered to be risk factors for MSDs (Punnett and Wegman 2004), the aim of the intervention was to address some of these in the preschool environment in order to reduce postural risk factors related to MSDs. Key aspects that were the focus of the intervention were awkward postures such as bending down at the waist, kneeling, stooping and squatting as these have been shown to be significantly associated with MSDs (Grant, Habes, and Tepper 1995; Okuno et al. 1997). As inappropriate furniture can result in awkward postures being adopted (Grant, Habes, and Tepper 1995) and has been associated with back pain (Cardoso et al. 2009), this was the motivation for the situation-orientated component of the intervention. The comparison of the pre-intervention and post-intervention results yielded significant differences in the durations of different ranges of postures adopted. Both the results from the CUELA posture classification and the duration of body angles as classified by ISO 11226 and EN 1005-4 yielded significant alterations following the intervention. The only significant biomechanical result was for moments greater than 135 Nm. The implications of these results will be discussed below, collectively grouped regarding the different postures, such as standing with trunk flexion and knee position with seated postures.

As preschool teachers are responsible for various tasks that require a close interaction with children and as the facilities are usually designed to be height-appropriate for children, awkward working postures are often adopted to obtain the required proximity to the child (Grant, Habes, and Tepper 1995), such as standing and bending at the waist down to the child. One example of tasks that may elicit this posture is changing the child's clothes (Grant, Habes, and Tepper 1995), as depicted in Figure 3(A). These awkward postures are often exacerbated and caused as a result of a lack of appropriate adult furniture in this environment (Grant, Habes, and Tepper 1995). The intervention aimed to reduce the amount of flexion by providing suitable seating options that had a range of seating heights as well as suggesting in the behaviour-orientated session to rather adopt a seated posture in certain situations. One such situation included adopting a seated posture as opposed to standing and bending down at the waist when interacting with the child. This element was selected for the intervention as it has been shown by Wong, Lee, and Yeung (2009) that working with a trunk flexion angle of greater than 60° increases the risk of low back pain. This change in posture following the intervention is depicted in Figure 3. The effects of the intervention appear to be reflected in the results as there was not only a significant decrease in trunk flexion in the range between 60° and 90°, but also a significant decrease in standing postures and an increase in the duration of seated postures occurred. The seats included in the intervention were height adjustable adult seats with a seat that panned to either side. As most of the participants used the available furniture in the rooms prior to the intervention, which consisted of static children chairs, the range of trunk motion was more limited than that possible on the new chairs introduced following the intervention. This may explain the significant changes in trunk rotation following the intervention. Trunk rotation classified as neutral significantly decreased and trunk rotation to the left significantly increased, indicating that the teachers adopted a less neutral posture, a possible negative effect of the intervention. This may be as a result of the new posture the teachers have adopted in order to interact with the child. Although not significant, the increase in trunk extension following the intervention was further investigated. Upon analysing the video data, the majority of the scenarios where this occurred was as a result of leaning back comfortably and not from adopting an awkward posture of trunk extension with no support.

Another main focus of the intervention was to reduce the number of knee-straining postures as these have been shown to be significantly associated with MSDs (Grant, Habes, and Tepper 1995). This was achieved by moving tasks usually performed while seated on the floor or in a kneeling position to a seated posture on one of the adult chairs that could be lowered sufficiently to reach the children tables. This is potentially reflected in the reduced percentages of the adopted knee-straining postures and the increase in the duration of seated postures shown by the results from the CUELA postural code. The duration of knee-straining postures was significantly reduced following the intervention from 8.4 to 3.1% of the shift, which constitutes a reduction from 40 ± 43 to 15 ± 21 min of time spent in knee-straining postures. This could have a potential effect on the risks of developing MSDs as it has been found that working at least 30 min per day in a keeling posture significantly increased the risk of knee osteoarthritis (Cooper et al. 1994). Although the percentage duration of the working day in which the knee posture was between 90° and 100° also significantly increased in the post-intervention phase, these results are to be analysed with caution as these joint angles can also originate while sitting in a chair of appropriate height.

For the calculated moments at the lumbosacral joint, a significant increase in the duration percentage occurred only in the category of moments above 135 Nm, which is classified as an increased risk. The results show a projected accumulated value of peaks where moments above 135 Nm occurred throughout the 8-h workday, and these peaks are very situation-dependant. Looking at the video data to see the cause for the increase in moments above 135 Nm revealed that the increase occurred in five of the six intervention preschools and was as a result of tasks whereby the intervention had no direct impact, such as setting up sporting equipment, and had not necessarily taken place prior to the intervention. This was further exacerbated by organisational factors such as missing staff.

The results suggest that specific physical risk factors may be altered with a combination approach of behavioural and situational intervention measures. A limitation of this study was the sample size ($n = 12$) but pragmatically a larger sample size was not feasible due to the nature of the complex methods applied and available intervention resources. However, very detailed data for the participants were collected which allowed for the development of suitable intervention measures. Another limitation was that an 8-h shift was calculated as opposed to measuring a complete 8-h shift directly. As it was not feasible to measure an entire 8-h shift, a reasonable trade-off to circumvent this limitation was to measure the same participants on two different days in the same week. Through the detailed documentation of the tasks that occur in an 8-h work day and the capturing of all the tasks at least once using the CUELA system, the limitations as a result of the data capturing length have been negated as much as possible. Caution is needed when generalising these results to other contexts, such as another country as there may be differences in behaviour, task structure and cultural aspects. Furthermore, the intervention measures were specifically tailored to the investigated preschools and, though some information may be transferable, others may not. Additional limitations include the lack of representation of the interaction of dynamic and static elements of the work performed as well as the expected limitations that are associated with field-based studies such as the lack of control of extraneous variables. Attempts were made to mitigate and reduce these limitations as much as possible but as the need to assess the current situational workload could not have been replicated under more stringent laboratory settings, some of these were unavoidable.

The strengths of this study include the objective nature of the results, specific research design elements and the practical application of the results. Objective data, which were normalised, were collected and used to inform the intervention measures and there was no loss in participants over the year between the data capturing phases. Furthermore, the postural assessments occurred for a relatively long time period (approximately 4 h per participant per day) and was repeated on a second day. As a result of the pragmatic and participatory approach used in the development of intervention measures and the study being conducted in real-life occupational settings of numerous preschools, the practical implications of the study were increased. An additional strength of this study was that the evaluated intervention measures were an end-product of this study. This may hopefully assist in the future design of preschools to minimise musculoskeletal stress during child handling (Grant, Habes, and Tepper 1995). A final strength of this study is that the recommendations made in previous studies have been considered and addressed. These included recommendations pertaining to intervention types and analysis methods. The recommendations pertaining to intervention types that were included consisted of the effect of environmental modification in the form of adult appropriate furniture (Cheng, Cheng, and Ju 2013; Grant, Habes, and Tepper 1995), and increasing preschool teacher's awareness of avoidable awkward postures (Grant, Habes, and Tepper 1995). The recommendations pertaining to analysis methods that were included consisted of capturing objective and observational data (Labaj et al. 2016) and the use of motion analysis to assess posture alignment (Cheng, Cheng, and Ju 2013).

5. Conclusion

The ErgoKiTa study aimed to determine the musculoskeletal strain of preschool teachers and provide evaluated prevention measures. This study hypothesised that based on the supplied intervention musculoskeletal strain indicators, consisting of knee flexion, trunk flexion, trunk rotation and moments at the L5/S1 joint, could be reduced when assessed in the post-intervention phase. The hypothesis can be partially accepted as the results yielded significant reductions in duration for particular postural categories specifically those related to knee-straining postures. Significant alterations in duration were determined for two categories of trunk flexion and for most of the categories of trunk rotation, with some of these results yielding an increase in non-neutral postures. These results highlight the need for further studies to determine the nature of these postures, whether they are static or dynamic, as well as the implications of these postures on the health of preschool teachers. For the biomechanical lumbar moment calculation, a negative result was obtained but this highlights the limitations of control in field-based studies. The benefit of incorporating a participatory approach in the intervention is highlighted in that significant alterations in postures occurred and, based on the results, suggestions for reducing awkward postures in the preschool environment can be drawn.

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ORCID

Eva-Maria Burford http://orcid.org/0000-0002-8509-9788

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