Role of the interaction between lumbar kinematics and accelerometer-measured physical activity in bodily pain, physical functioning and work ability among health care workers with low back pain

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Abstract

The aim of this study was to examine the associations of spinal kinematics and physical activity (PA) with bodily pain, physical functioning, and work ability among health care workers with low back pain (LBP). Spinal kinematics and PA were measured with a wireless Inertial Measurement Unit system (ValedoMotion®) and a waist-worn tri-axial accelerometer (Hookie AM20), respectively. Their association was assessed in relation to Work Ability Index (WAI), bodily pain and physical functioning (RAND-36) in 210 health care workers with recurrent LBP. Greater lumbar movement variability (in angular velocity) during a "Pick up box" functional task was correlated with higher amounts of step counts (r=-0.29, p=0.01) and moderate PA (r=-0.24, p=0.03). A higher amount of PA (p=0.03) as well as less movement control impairment (p=0.04) and movement variability (p=0.03) were associated with greater work ability, whilst greater vigorous PA was the only parameter to explain higher physical functioning (p=0.02). PA and movement variability were relative to each other to explain bodily pain (p=0.01). These findings show the importance of considering the interaction between lumbar kinematics and physical activity while planning strategies to improve bodily pain, physical functioning and work ability among health care workers with LBP.

Keywords: Movement; physical activity; accelerometry; low back pain

1. Introduction

Low back pain is the most common musculoskeletal conditions and a leading cause of disability (Hartvigsen et al., 2018, James et al., 2018). However, the exact cause of low back pain remains unclear in most cases (Maher et al., 2017). Low back pain is considered to be multifactorial, where genetic, biopsychosocial, psychological and social factors play a substantial role (Hartvigsen et al., 2018). The prevalence of low back pain in certain professions is substantially higher than in others. For example, among nurses a high prevalence of low back pain has been reported globally to be 64% in Africa, 72% in the United States of America, 77% in Turkey and 91% in Japan (Josephson et al., 1997, Karahan et al., 2009, Kasa et al., 2020, Smith et al., 2003). High workload and stress for nurses in addition to the nature of the job tasks such as patient-handling activities are believed to be risk factors for developing low back pain causing reduced productivity and presenteeism (Holtermann et al., 2013, Vinstrup et al., 2020, Yoshimoto et al., 2020). Increased spinal kinematics, less structured movement variability and moderate physical activity appear to positively affect low back pain in general but studies that investigated the role of these spinal movements and physical activity in nurses with low back pain are lacking (Alzahrani et al., 2019, Bauer et al., 2019, Sadler et al., 2017, Scholtes et al., 2009, Wernli et al., 2020).

People with low back pain appear to move differently than those without low back pain, and alterations in spinal kinematics and movement control are often associated with low back pain (Laird et al., 2014, Scholtes et al., 2009, Wernli et al., 2020). Therefore, they are commonly targeted impairments in the management of low back pain. Aberrant spinal movements may result in abnormal loading that can contribute to tissue degeneration, potentially leading to pain and other symptoms (Iorio et al., 2016). Importantly, a systematic review of prospective cohort studies reported that restricted range of motion in the frontal plane contributes to predict the risk of developing low back pain (Sadler et al., 2017). Adequate movement variability also appears to help prevent pain or injury from repetitive and physically demanding work tasks (Madeleine et al., 2008). A randomized controlled trial of a six—month neuromuscular training for nurses with low back pain reported that lumbar movement variability (angular displacement) improved significantly in the intervention group compared to the control group. This suggests that movement variability, particularly less structured movement variability could play an important role in neuromuscular functional integrity and safe patient handling practices among nurses with low back pain (Bauer et al., 2019). Although the effects of these movement characteristics on low back pain have been examined individually, simultaneously examining the interaction and association between these movements in relation to low back would help to better understand the nature of these movement characteristics and provide important insights into the management and prevention of low back pain.

Promoting moderate physical activity and reducing sedentary behavior appear to benefit individuals with low back pain, whilst higher levels of physical fitness have been shown to be associated with a lower prevalence of low back pain (Alzahrani et al., 2019, Barone Gibbs et al., 2018, Heneweer et al., 2012). Cross sectional and cohort studies have demonstrated that people undertaking moderate levels of physical activity during their leisure time had a lower odds of having low back pain than those engaging in low levels of physical activity (Alzahrani et al., 2019). In addition, interventions promoting physical activity and reducing sedentary behavior in sedentary workers have been shown to reduce back pain related disability (Barone Gibbs et al., 2018), implying that promoting moderate levels of physical activity, occupational activity and physical fitness, as well as reducing sedentary behavior are beneficial for people with low back pain. Although a high prevalence of low back pain has been frequently reported among nurses, studies that investigated the role of physical activity and spinal movements in relation to the job performance of nurses with low back pain are lacking.

Therefore, the aim of the present study was to investigate the correlation between spinal kinematics, movement control and accelerometer-measured physical activity, and their contribution to physical performance among nurses with low back pain.

2. Methods

The present study employed a cross-sectional design to explore the interaction between lumbar kinematics and accelerometer-measured physical activity in relation to low back pain among health care workers. We obtained data for this cross-sectional study as part of a randomized controlled trial (the NURSE RCT, clinical trial registration NCT01465698) (Suni et al., 2016). The study was conducted in accordance with Helsinki Declaration, approved by the Ethics Committee of Tampere University Hospital, Finland (ETL code R08157) and informed consent was obtained from all participants.

2.1. Participants

Female health care personnel, aged between 30 and 55 years, who had worked at their current job in physically demanding patient work for at least 12 months, and experienced low back pain with a minimum pain intensity of two on the numeric rating scale (NRS; 0-10) in the past 4 weeks were recruited into the study. Participants were excluded if they had a history of any serious back injury, chronic or self-reported continuous low back pain with duration of 7 months or longer, other diseases or symptoms interfering with participation in moderate-intensity neuromuscular exercise, regular engagement in neuromuscular exercise more than once a week, or if they were pregnant or postpartum in the past 12 months. The majority (87%) of the participants were nurses or nursing assistants, whilst the rest of the participants were physiotherapists/physiotherapy assistants (5%), radiographers and laboratory technicians (4%), midwifes (3%) and ward head nurses (1%). All the participants were engaging in physically demanding work tasks such as patient handling activities. 82% of the participants had low back pain in some or most days of the week, and 18% had daily pain.

2.2. Measurements in relation to physical performance

Bodily pain

Pain domain of the Finnish validated version of RAND-36 Health Survey designed to measure quality of life was used to assess bodily pain hindering normal work in the past four weeks (Aalto AM et al., 1999, Hays et al., 1993). The bodily pain domain comprising two questions describes the intensity of bodily pain and pain interfering with normal work using 5-point and 6-point scales, respectively. The sum of the scores of the two questions was converted into scores from 0 to 100 using the conversion equation provided by Ware & Sherbourne, where 0 indicates very severe pain and extreme difficulties and 100 indicates no pain and no difficulties (Ware & Sherbourne, 1992).

Physical functioning

The sum of the scores of 10 questions belonging to the physical function domain of the RAND-36 was used to determine current limitations in typical daily activities. The domain comprises of 10 items describing the extent to which their health interferes with the following daily activities, namely, vigorous activities; moderate activities; lifting or carrying groceries; climbing several flights of stairs; climbing one flight of stairs; bending, kneeling, or stooping; walking about 2 km; walking approximately 500 m; walking one block; bathing or dressing. A 3-point scale (limited a lot, limited a little, not limited at all) was used to assess each item, and the sum score of the 10 items was then converted into scores from 0 to 100, where 0 indicates "limited a lot" and 100 indicates "not limited at all" (Ware & Sherbourne, 1992).

Work ability index

The short form of "Work Ability Index" consisting of 4 questions was used to describe current work ability (0–10; where 0 = unable to work and 10 = the best possible), work ability in relation to physical (1–5; 1 = very poor, 5 = very good) and mental (1–5; 1 = very poor, 5 = very good) work demands, and estimation of own work ability in 2 years' time (1 = unlikely to work, 4 = ”not certain”, 7 = almost certain to work) (Ilmarinen, 2009). The sum score of each item ranged from 3 to 27, where 3 indicates a poor work ability, 27 indicates the best work ability.

2.3. Measurements in relation to movements

Lumbar kinematics (range of motion, determinism of angular displacement and velocity)

A wireless inertial measurement unit (IMU) system, (ValedoMotion®, Hocoma AG, Volketswil, Switzerland) was used to measure lumbar range of motion (angular displacement) in the sagittal plane as well as angular velocity during a "Pick Up a Box" test. To measure lumbar movements, the IMU system uses two sensors attached at the level of the sacrum (S2) and the first lumbar vertebra (L1), as described in a previous study (Bauer, Rast, Ernst, Kool, et al., 2015). The raw data from the IMU system was sampled at 50 Hz (Valedo® Research, Hocoma AG) and transformed into quaternions (Bauer et al., 2019, Madgwick et al., 2010). The angular difference was derived from the quaternions using the tilt/twist formulation (Crawford et al., 1999). The differential signals of the S2 and L1 sensors were used to calculate the lumbar spine angle in the sagittal, transversal and frontal planes defined by the global coordinate system. Lumbar range of motion was determined in the sagittal plane, where flexion and extension movements were expressed as positive and negative values, respectively. The alignment of the two sensors was set at an angle of zero degrees. The angular displacement was filtered using a second order zero-phase low-pass Butterworth filter (1 Hz cut-off frequency), and the filtered data was used to calculate angular velocity. Determinism of angular displacement and velocity was determined during the "Pick Up a Box" test of five cycles, each lasted 4.8 s. A metronome set at 50 bpm was used to control the cycles. Determinism indicates the degree of the structure of movement variability and, furthermore, a higher movement determinism indicates less structured movement variability (more variable movement patterns). During each cycle, participants were asked to stand first and then squat to pick up a box weighing 10% of the participant's body weight from the floor and return to the squat position (Bauer et al., 2019, Bauer, Rast, et al., 2015b). Valid estimates and reliable measures for determinism of lumbar movement, along with the data processing steps were explained in a previous study (Bauer, Rast, et al., 2015a). Spinal flexibility in the frontal plane was assessed by measuring distance between the middle-fingertip positions marked on the lateral thigh in the upright position with arms kept at the sides of the body and then at the maximum lateral flexion (Suni et al., 1996).

Movement control impairment

Movement control impairment of the lumbar spine was assessed as described by Luomajoki et al using a set of four tests of the movement control impairment test battery, (Luomajoki et al., 2007, Luomajoki et al., 2008), namely waiters bow, pelvic tilt, sitting knee extension and knee flexion in prone. The total score of movement control impairment was obtained by summing the scores of each test. The total score therefore ranged 0 to 4, where 0 indicates no movement control impairment and 4 indicates maximum movement control impairment.

Physical activity

After the measurement session in relation to lumbar kinematics and movement control impairment, physical activity over a period of seven consecutive days was measured with a waist-worn tri-axial accelerometer (Hookie AM20, Traxmeet, Espoo, Finland) during waking hours. Participants were instructed to wear the Hookie for seven consecutive days, excluding water-based activities. The sampling frequency of the accelerometer was 100 Hz, and the accelerometer measured acceleration within ± 16 g range with 4 mg resolution. Validated mean amplitude deviation (MAD) method was used for analysis of accelerometer data in 6 sec epochs (Vähä-Ypyä et al., 2015). Moderate-intensity physical activity (MPA) was defined as 3.0-5.9 METs (MAD 91-414 mg), and vigorous physical activity (VPA) as ≥ 6.0 METs (MAD > 414 mg). Moderate intensity physical activity (MPA) was defined as 3.0-5.9 METs (MAD 91-414 mg), and VPA as ≥ 6.0 METs (MAD > 414 mg). Physical activity is moderate, if the participant is able to talk despite shortness of breath. Physical activity is vigorous, if talking is difficult due to shortness of breath (Ainsworth et al., 2011, Vähä-Ypyä et al., 2015). In the analysis these were presented as accumulated time in minutes separately for both intensity levels. Number of daily steps was determined by an algorithm that splits the detected acceleration into vertical and horizontal components. The vertical component is band-pass filtered (1-4 Hz) and positive values are integrated. Steps are detected when the integral value exceeds the specified limit. The step detection algorithm requires walking speed of about 3 km/h to detect every step (Vähä-Ypyä et al., 2018).

2.4. Statistical analysis

Descriptive statistics and inferential analyses were performed using the IBM SPSS statistical analysis software, version 28. In the descriptive statistics, mean values and standard deviations (SD) for participant characteristics, including age, body mass index, lumbar kinematics, physical activity and physical performance were determined. Shapiro-Wilk test was used to check for data normality. Correlation between movement variables were determined using Spearman's Rank correlation coefficient. In the inferential analyses, generalized linear models were used to assess the role of spinal movements and physical activity to explain physical performance. Physical functioning, work ability and bodily pain were selected as dependent variables, whilst spinal kinematics, movement control impairment and physical activity were assessed as independent variables. To consider the effect of different confounding factors, the based models were adjusted for age, BMI, work and fear-avoidance beliefs related to physical activity. The strengths of associations were compared using standardized beta coefficients. Standardized beta coefficients are estimated in units of standard deviation, allowing to compare the strength of associations of different independent variables with the dependent variable. Standardized coefficients were calculated by dividing the multiplication between the raw regression coefficient and the standard deviation of the independent variable by the standard deviation of the dependent variable. P values less than 0.05 were considered as statistically significant.

3. Results

Spinal kinematics, physical activity and physical performance data were collected from 210 healthcare personnel with low back pain, except for lumbar movement determinism and range of motion in the sagittal plane measured in 78 of those participants. Characteristics of the study sample are presented in Table 1.

3.1. Correlations between physical activity, spinal kinematics and movement control impairment

Higher step counts (r=-0.29, p=0.01) and more minutes of moderate physical activity (r=-0.24, p=0.03) were correlated with a lower movement determinism of angular velocity (more movement variability or less deterministic movement), whilst increased minutes of vigorous physical activity was correlated with reduced impairment in lumbar movement control (r=-0.17, p=0.01) (Fig. 1).

Additionally, participants who had less impairment in lumbar movement control demonstrated smaller lumbar range of motion (r=0.32, p=0.003) during the “Pick up box” functional task.

3.2. Associations of spinal kinematics and physical activity with physical performance

Work ability and bodily pain were explained by several dependent variables whereas physical functioning was explained by only one dependent variable (Fig. 2). More minutes of vigorous physical activity was associated with greater work ability and physical functioning, but the strength of association was higher for work ability than for physical functioning (Table 2, Fig. 2). Higher lumbar movement determinism/less lumbar movement variability of angular velocity and step counts explained greater work ability but associated with lower bodily pain scores. The strength of association was higher for bodily pain than for work ability. Reduced bodily pain scores were also found to be associated with increased lumbar movement determinism/decreased lumbar movement variability of angular displacement. A statistically significant positive interaction was observed between step counts and lumbar movement determinism of angular displacement and velocity on bodily pain (Table 2).

4. Discussion

The purpose of the current study was to examine the correlation between spinal kinematics, movement control and physical activity, and their contribution to physical performance among health care personnel with recurrent/fluctuating low back pain (in the past 4 weeks) who had a high risk for chronicity of low back pain due to physically heavy work. The key findings from the present study were as follows: 1) Higher amounts of step counts and moderate physical activity were correlated with increased movement variability (less deterministic movement), whilst increased participation in vigorous physical activity was correlated with reduced impairment in lumbar movement control. 2) Greater physical performance involving physical functioning, work ability as well as bodily pain were associated with less movement control impairment and movement variability, as well as a higher amount of physical activity but not with the spinal flexibility in the frontal plane.

Increased movement variability (less deterministic movement) was correlated with higher amounts of moderate physical activity and step counts. In other words, physically active nurses had a higher lumbar movement variability/less structured movement variability during the “Pick Up Box” task than those who are less active. Having sufficient movement variability in individuals involved in physically demanding work could potentially prevent pain from repetitive occupational tasks as described in the earlier study (Madeleine et al., 2008). The findings from the present study therefore implies that being active may contribute to reduce the risk of musculoskeletal injury or low back pain among nurses associated with their physically demanding work tasks including patient handling activities as physical activity was positively correlated with lumbar movement variability. People with low back pain who engage in moderate physical activity have a better prognosis than those who do not (Alzahrani et al., 2019). However, the mechanism through which physical activity is beneficial for low back pain remains unclear. Thus, the results from the current study could be an important insight into a better understanding of part of many potential underlying mechanisms by which physical activity benefits people with low back pain. Future studies are needed to explore if the association is the case in different tasks replicating repetitive or physically demanding work activities, and then establish whether a causal relationship exists between physical activity and lumbar movement variability. To the best of our knowledge no studies to date have explored lumbar movement variability in relation to accelerometer-measured physical activity.

Less impairment in lumbar movement control was correlated with smaller lumbar range of motion during the “Pick Up Box” task and a higher amount of vigorous physical activity. Clinical instability of the lumbar spine is believed to be one of the factors closely associated with maladaptive movement control (Ben-Masaud et al., 2009, Luomajoki et al., 2007). Additionally, a cross sectional study of 49 patients with low back pain examining the association between the presence of lumbar instability detected by radiography and the clinical presentation reported that individuals who had lumbar flexion more than 53 degrees were 4.3 times more likely to have radiographic lumbar instability (Fritz et al., 2005), supporting the positive correlation between movement control impairment and lumbar range of motion found in the current study. These results therefore suggest that increased maximal lumbar range of motion during functional tasks replicating repetitive occupational activities such as patient handling practices among nurses could be a useful indication for the identification of impaired lumbar movement control.

The present study also found that nurses engaging in more minutes of vigorous physical activity had less movement control impairment than those undertaking less vigorous physical activity. Studies that specifically investigated movement control impairment of the lumbar spine in relation to physical activity are lacking. Nevertheless, several studies have examined physical activity in relation to falls in elderly found that physical activity is crucial to stimulate postural control (Bianco et al., 2014, Campbell et al., 1997, Patti et al., 2021). Furthermore, randomized controlled trials found that promoting physical activity improved postural control needed to prevent falls (Campbell et al., 1997, Patti et al., 2017), suggesting physical activity could play an important role in movement control. Although literatures state that people with low back pain do not appear to benefit from undertaking vigorous physical activity compared to engaging in moderate levels of physical activity (Alzahrani et al., 2019), low back pain patients with motor control impairment may benefit from engaging in vigorous physical activity as the current study found that more minutes in vigorous physical activity was associated with less movement control impairment. However, future longitudinal research is needed to establish a causal relationship between movement control impairment and vigorous physical activity.

Physical performance involving work ability, physical functioning as well as bodily pain was associated with movement control impairment, movement variability and physical activity but not with the spinal flexibility during the functional task. Work ability among nurses was positively associated with vigorous physical activity and step counts but the strength of association was higher for step counts than for vigorous physical activity. Participation in physical activity is generally believed to be beneficial to both healthy individuals and people with musculoskeletal disorder including low back pain as it has well-established health benefits (Alzahrani et al., 2019, World Health Organization, 2020). Additionally, a randomized control study of 200 female healthcare workers from Danish hospitals found that participants who chose to engage in a physical exercise program at work had a higher work ability index than those participating in a home-based exercise program after 10-week follow-up (Jakobsen et al., 2015). The findings from this randomized controlled trial supports our results, and also emphasize the importance of participating in physical activity at workplace among nurses to promote their work ability. The present study also showed that work ability was inversely cross-sectionally associated with movement control impairment, suggesting movement control impairment might be an important factor to be considered in reduced work ability. This unanticipated result makes sense considering that movement control impairment is classified as a sub-group of chronic low back pain, which substantially reduce work ability (O'Sullivan, 2005, Yoshimoto et al., 2020). Less structured movement variability/increased movement variability, although critical in preventing pain or injury from repetitive and physically demanding work tasks (Madeleine et al., 2008), was inversely associated with work ability. This result suggests that other nursing tasks or activities needed in the work ability may require more deterministic movement. However, this association needs to be confirmed and further explored during various nursing tasks in future studies as nursing care requires a range of physically demanding activities contributing to the work ability. In terms of bodily pain interfering with work, the positive effect of movement variability on bodily pain was dependent on step counts as an interaction effect between these two explanatory variables was significant. This means nurses with less structured movement variability and lower step counts had a lower pain interfering with work than those with more structured movement variability and higher step counts. This result overall suggests that movement variability and physical activity (step counts) are relative to each other in bodily pain among nurses, rather than separately.

The main limitation of the current study was the cross-sectional design, which cannot provide evidence on whether the nature of the association between physical activity, spinal kinematics and low back pain related measures is causal. The regression coefficients found in the current study were relatively small, which need to be considered when interpreting the associations found between physical activity, spinal kinematics and measures in relation to low back pain. The data of the present study were obtained from the baseline data from the NURSE RCT, conducted in the three consecutive sub-studies in different workplaces. As spinal kinematics were measured only in the last sub-study involving 78 personnel, the statistical analysis of spinal kinematics in relation to the other parameters, such as physical activity was conducted on the data from only 78 personnel out of total 210 participants in the present study. Additionally, there was no control group (without low back pain) in the present study to investigate the relationships, suggesting the future studies may consider this to better understand the associations of spinal kinematics and physical activity with low back pain.

5. Conclusions

Higher amounts of step counts and moderate physical activity were correlated increased movement variability, whilst a higher amount of vigorous physical activity was correlated with reduced impairment in lumbar movement control. A higher amount of physical activity as well as less movement control impairment and movement variability were associated with greater work ability, whilst greater vigorous physical activity was the only parameter to explain higher physical functioning. Physical activity and movement variability were relative to each other to explain bodily pain. The findings from the current study contribute to a better understanding of the association between spinal kinematics and physical activity, and underline the obvious importance of considering the interaction between physical activity and spinal kinematics while planning strategies to improve bodily pain, physical functioning and work ability among health care workers with low back pain.

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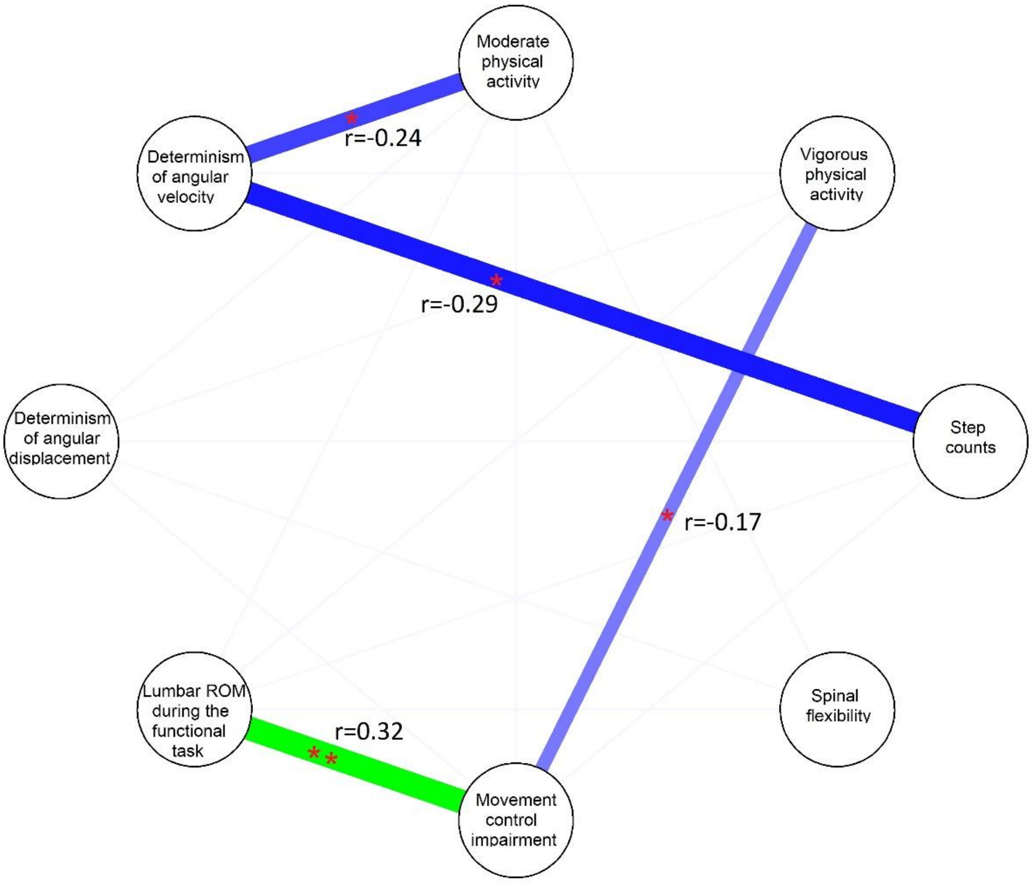
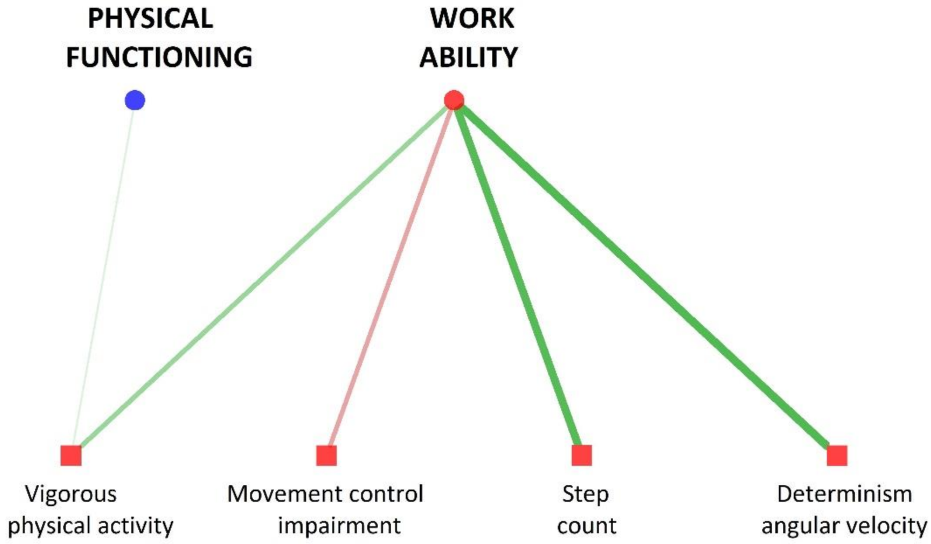
Fig. 1. Correlations between movements in the health care personnel with low back pain



** p<0.05, **p<0.01, as noted above the blue and green lines indicate negative and positive correlations respectively, and the color and width of the lines indicate the strength of correlations. Faded lines indicate non-significant correlations. A lower determinism means more movement variability or less deterministic movement. ROM – range of motion, r – correlation coefficient*

Fig. 2. Comparison of the associations of spinal kinematics and physical activity with physical performance by standardized regression coefficients



As noted above the red and green lines indicate negative and positive associations respectively, and the color and width of the lines indicate the strength of associations expressed in standardized coefficients. Stronger associations were indicated with the circles (dependent variable) and squares (independent variables) of the same color.