Bachelor's thesis

NTNU
Norwegian University of Science and Technology
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Department of Neuromedicine and Movement Science

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Kinematic, kinetic and electromyographical differences between individuals with and without low back pain when lifting

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Supervisor: Ingebrigt Meisingset
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Abstract

Background: Lifting is considered a risk for low back pain (LBP). Evidence for relationships between lifting and LBP is found in occupational studies, but biomechanical factors when lifting and subsequent relationships with LBP are unclear.

Aim and purpose: To present and investigate kinematic, kinetic, and electromyographical differences between individuals with and without LBP when lifting. Identifying altered biomechanical factors present in LBP individuals when lifting, enable investigations of how these factors relate to LBP.

Methods: The study was conducted as a narrative review. Two databases were systematically searched 19.02.2024. Additionally, relevant literature references were searched. Included studies were peer reviewed randomized control or clinical trials comparing idiopathic chronic LBP individuals and controls when lifting.

Results: Nine cross-sectional studies were included. Two studies found that LBP individuals lifted with a more vertical inclined truncus, and two studies found movement patterns with less variation compared to controls. Furthermore, four studies found that individuals with LBP lifted more slowly, and four studies found increased muscle activity compared to controls.

Conclusion: Individuals with LBP exhibited altered movement patterns compared to controls, demonstrating decreased velocities and increased muscle activities when lifting.

Abstrakt

Bakgrunn: Løfting anses som en risiko for korsryggsmerter. Bevis for sammenhenger mellom løfting og korsryggsmerter finnes i arbeidsrelaterte studier, men biomekaniske faktorer ved løfting og påfølgende forhold til korsryggsmerter er uklare.

Mål og hensikt: Å presentere og undersøke kinematiske, kinetiske og elektromyografiske forskjeller mellom individer med og uten korsryggsmerter når de løfter. Kartlegging av endrede biomekaniske faktorer til stede hos individer med korsryggsmerter når de løfter, muliggjør å undersøke sammenhengen mellom disse faktorene og korsryggsmerter.

Metode: Ble gjennomført som et litteraturstudie. To databaser ble systematisk søkt den 19.02.2024, i tillegg til referanser i relevant litteratur. Inkluderte studier var fagfellevurderte randomiserte kontroll- eller kliniske studier som sammenlignet individer med og uten idiopatiske kroniske korsryggsmerter når de løfter.

Resultater: Ni tverrsnittsstudier ble inkludert. To studier fant at individer med korsryggsmerter løftet med en mer vertikal trunkus, og to studier fant bevegelsesmønstre med mindre variasjon. Videre fant fire studier at individer med korsryggsmerter løftet langsommere, og fire studier fant økt muskelaktivitet blant dem.

Konklusjon: Individer med korsryggsmerter viste endrede bevegelsesmønstre sammenlignet med individer uten korsryggsmerter, ved reduserte hastigheter og økt muskelaktivitet når de løft

1. Introduction

Low back pain (LBP) is prevalent across the globe with more than 600 million people affected in 2020, and an expectancy to exceed 800 million affected by 2050 (WHO, 2023). It is the single leading cause of worldwide disability, and is in approximately 90 % of cases idiopathic (WHO, 2023). Assessing etiological and epidemiological factors for LBP is a complex and difficult endeavor, complicated by the fact that pain is inherently subjective and highly modulatory. There are substantial amounts of research regarding LBP, and lifting is regarded as a risk for LBP (Arbeidstilsynet, n.d.; Helsenorge, 2023; WHO, n.d.). Evidence for associations between lifting and LBP is found in occupational studies and in relation to relative exposures of lifting; duration, frequency and intensity (B. Amorim et al., 2019; Coenen et al., 2014). Although lifting is considered a risk, biomechanical factors present in various ways of lifting, and subsequent relationships with LBP remain largely unknown.

Identifying biomechanical causations for LBP has been attempted, most notably capacities and mechanisms of the lumbar intervertebral discs when mechanically loaded. In vivo and cadaveric measurements of lumbar spinal segments revealed increased intradiscal pressures present in flexed spinal postures, and was deemed a plausible causation for deformations, herniations and tissue damage, eliciting pain (Adams & Dolan, 1996; Adams & Hutton, 1982, 1983; Nachemson, 1975). Accordingly, lumbar spine posture when lifting was viewed important for LBP, and ways of decreasing the load on the back emphasized by promoting and providing ergonomic and postural advice (Nachemson, 1975).

This understanding of a correct load-decreasing, and a wrong load-increasing way of lifting is highly present in the population, and substantial amounts of negative "back-beliefs" among healthcare professionals is present, with inherent views of the back as weak and injury-prone (Caneiro et al., 2018; Nolan et al., 2018, 2022; Rialet-Micoulau et al., 2022). Utilization and implementation of interventions based on these load-reducing principles have not reduced LBP (Martimo et al., 2008; Van Hoof et al., 2018; Verbeek et al., 2012). Furthermore, several more recent studies have reported conflicting results that question the understanding of wrong load-increasing ways of lifting, tissue damage and deformation, and LBP (Brinjikji et al., 2015; Masui et al., 2005; Mawston et al., 2021; Saraceni et al., 2020).

As mentioned, occupational evidence associating lifting and LBP provides no insight regarding biomechanical factors when lifting, nor operationalize lifting through biomechanical measurements. It rather states that occupational lifting beyond certain thresholds is associated with LBP (Coenen et al., 2014). Conflicting evidence is also present (Kwon et al., 2011). Characterizing utilized ways of lifting by objectively measurable kinematic, kinetic and electromyographical values, present a valid way of assessing biomechanical factors present when lifting. Detailed biomechanical measurements of factors present in utilized ways of lifting can be assessed, instead of characterization in terms of a working situation (e.g. manually handling patients) or lifting postures, positions, or techniques (stoop, flex, squat). Differentiating groups by LBP status enable identifying biomechanical factors present in LBP individuals when lifting, and investigations of these factors' relationships with LBP.

Three reviews have been identified as to previously investigate kinematic, kinetic and electromyographical differences between individuals with and without LBP when lifting (Abd Rahman et al., 2023; Nolan et al., 2020; Saraceni et al., 2020). However, Rahman and colleagues (2023) investigated various activities where a minority of included studies assessed lifting activities. Saraceni et al. (2020) assessed differences in lumbar spine flexion, but not hips or knees. Lastly, the review by Nolan and colleagues (2020) is similar in both aim and approach but largely leaves out measured values, and rather present results in terms of lifting techniques operationalized through biomechanical data. Our review also includes different studies due to methodology and a more recent literature search. The aim of this review is to present and investigate kinematic, kinetic, and electromyographical differences between individuals with and without LBP when lifting.

2. Methods

The study was conducted as a narrative review. An electronic systematic search was conducted 19.02.2024 using databases SPORTDiscus and PubMed, combining keywords (using OR) within three search-components (**1** AND **2** AND **3**). **1**: "Low back pain", "lower back pain", "LBP". **2**: "Lift*", "lifting technique", "lifting posture". **3**: "Kinetic*", “kinematic*”, “biomechanic*”, “mechanic*”, “EMG”, “muscle activity”. The original search generated 889 results. Applying filters yielded 232 results. Six of the nine studies presented were deduced from manually assessing these 232 titles, abstracts and/or full texts, as they met the inclusion and exclusion criteria presented below. The remaining three studies were found in relevant literature references.

2.1 Inclusion and exclusion criteria

Studies were included if published after 1999, written in English and were peer reviewed randomized control or clinical trials. Studies assessing lifting by at least two subgroups based on LBP-status (LBP and control) were included. Study interventions included various lifting tasks relevant for occupational settings such as lifting with or without external loads, repetitive and singular lifts, from varying positions both dynamically and statically. The LBP-group had to consist of idiopathic, chronic individuals and was required to be age-matched with controls. Excluded studies were published before 1999, assessed activities unrelated to lifting, or dynamically performed lifts only assessing parts of a “full” lifting cycle.

3. Results

3.1 Characteristics

A detailed description of characteristics for the included studies can be found in table 1. Overall, the total number of participants across the 9 included studies was 436. Most studies included participants who were age- and gender matched with both males and females, except for in two studies (Larivière et al., 2000, 2002) where the participants were all males. In one study (Ferguson et al., 2004), LBP individuals had a significant height difference, without a significant difference in weight, compared to controls. In terms of study design, all included cross-sectional studies compared at least one LBP-group with controls. However, one study (Pranata et al., 2018) categorized the LBP-group into “high” and “low” disability subgroups, which henceforth will be referred to as LBP_{high} and LBP_{low}. All studies assessed idiopathic chronic LBP, where the definition of “chronic” varied across the included studies ranging from at least 2 months to at least 6 months.

3.2 Lifting task, measurements and findings

Detailed information regarding the type of lifting task, measurements, and relevant findings are described in Table 2. Across the included studies, various lifting tasks were utilized, involving both symmetrical and asymmetrical lifts, with and/or without an external load from different horizontal and/or vertical locations relative to the participant. However, in one study (Yang, 2018) participants performed three static stoop lifts with and without external load. Regarding measurement methods, most studies incorporated a combination of kinematics, kinetics, and muscle activity assessments, although with varying methodologies. Two studies (Dideriksen et al., 2014; Sung, 2013) measured only kinematics and one study (Yang, 2018) exclusively examined muscle activity. Additionally, two studies (Dideriksen et al., 2014; Pranata et al., 2018) presented measurements highlighting movement variation between groups.

Table 1: Descriptives of included studies

Study	Country	Study design	Subjects	Age (yrs)	Gender (f, m)	Pain descriptives
Dideriksen et al., 2014	Germany	Cross-sectional	Total = 34 LBP = 17 Controls = 17	LBP = 32.5 ± 9.6 Controls = 29.7 ± 7.3	LBP = 59% f, 41% m Controls = 53% f, 47% m	NRS = 1.8 ± 1.5
Ferguson et al., 2004	Unknown	Cross-sectional	Total = 123 LBP = 62 Controls = 61	LBP = 38.4 ± 9.9 Controls = 36.8 ± 10.1	LBP = 30 f, 32 m Controls = 30 f, 31 m	Pain scale (0-10) = 5.0 ± 1.9 Duration (months) = 10.2 ± 13.6
Larivière et al., 2000	Unknown	Cross-sectional	Total = 33 LBP = 15 Controls = 18	Non-specific CLBP = 40 ± 4 Controls = between 35 and 45	Only males	VAS = 3.2 ± 2.9
Larivière et al., 2002	Unknown	Cross-sectional	Total = 33 LBP = 15 HC = 18	LBP = 40 ± 4 Controls = 39 ± 3	Only males	VAS = 2.6 ± 2.5

Table 1 (continued)

Marras et al., 2001	Unknown	Cross-sectional	Total = 44 LBP = 22 Controls = 22	LBP = 39.0 ± 10.1 Controls = 36.4 ± 11.1	LBP = 10 f, 12 m Controls = gender- matched, no further description	Duration (weeks) = 35.5
Pranata et al., 2018	Australia	Cross-sectional	Total = 52 LBP_{high} = 18 LBP_{low} = 25 Controls = 29	LBP_{high} = 46.7 ± 11.8 LBP_{low} = 42.3 ± 11.1 Controls = 37.8 ± 11.5	LBP_{high} = 12 f, 6 m LBP_{low} = 11 f, 14 m Controls = 17 f, 12 m	NRS (LBP_{high}) = 4.5 ± 1.9 NRS (LBP_{low}) = 3.0 ± 1.6
Saraceni et al., 2021	Unknown	Cross-sectional	Total = 41 LBP = 21 Controls = 20	LBP = 37.7 (31.1 – 44.2) Controls = 32.5 (27.6 – 37.4)	LBP = 7 f, 14 m Controls = 6 f, 14 m	Previous week (0-10) = 3.5 (2.7 – 4.3) Entering lab = 1.9 (1.3 – 2.6)
Sung et al., 2013	South-Korea	Cross-sectional	Total = 30 LBP = 15 Controls = 15	LBP = 37.15 ± 14.55 Controls = 41.82 ± 16.81	No gender difference	ODI = 21.66 ± 7.44%
Yang, 2018	Unknown	Cross-sectional	Total = 46 LBP = 28 Controls = 28	LBP = 23.75 ± 3.51 Controls = 22.67 ± 1.38	Gender-matched, no further description	VAS = 3.89 ± 0.73

M: female, M: male, Yrs: years, LBP: low back pain, VAS: Visual Analog Scale, NRS: Numerical Rating Scale, ODI: Oswestry Disability Index

Table 2: Results of included studies with differences for LBP-group compared to controls

Study	Lifting task	Measurements	Differences for LBP-group
Dideriksen et al., 2014	One repetitive cycle lifting a 5 kg box for 1 second from "low shelf" (knee-height) to "high shelf" (shoulder height), maintaining contact for 3 seconds, lifting the box back to low shelf and wait 3 seconds. Performed 20 cycles to a metronome, total duration ca. 3 min.	**Kinematic** = spine angles **%DET** = percentage of determinism	**Kinematic and %DET** = no significant difference of %DET for task-related angular movement. Significant higher for accessory angular movement for 8/12 sensors.
Ferguson et al., 2004	Four different weights (4.6 kg, 6.8 kg, 9.1 kg and 11.4 kg) lifted from five positions; "shoulder", "waist", "knee", "waist-far" and "knee-far", ending upright with elbows at 90 degrees. "Far" positions had a moment arm at 60 cm, remaining at 30 cm. Symmetrical and asymmetrical lifts, self-selected technique.	**Kinematic/kinetic =** timing of peak sagittal position, lumbar motion, velocity, and acceleration of the spine **EMG =** temporal muscle activity	**Kinematic/kinetic** = Sagittal peak position occurred significantly later for knee (10%), waist-far (7%) and knee-far (8%) conditions
Larivière et al., 2000	Six randomized lifts repeated for three consecutive cycles to a metronome with knees and elbows straight. Full flexion/extension of the trunk in sagittal or the frontal plane with and without a 12 kg box returning to upright position.	**Kinematic** = maximal trunk angles **Kinetic** = two force plates and a dynamometric box **EMG** = lumbar- and thoracic erector spinae, latissimus dorsi, rectus abdominis, external- and internal oblique	**Kinematic** = no significant sagittal difference for maximal trunk angels **Kinetic =** no significant sagittal difference **EMG =** significant increased for left TES during flexion-extension with load. Significant left-right asymmetries for thoracic erector spinae with increased sagittal activity for left without load.

Table 2 (continued)

Larivière et al., 2002	12 kg box lifted from the ground; (1) in symmetric sagittal plane to hip height, (2) asymmetrical to shelf 90 degrees to the right of the subject. Both tasks ended with lowering the box to the ground. Lifted with self-selected pace and technique.	**Kinematic** = L5/S1 loading, angles in trunk and lower body **Kinetic** = trunk velocity and acceleration **EMG** = biceps femoris, lumbar- and thoracic erector spinae	**Kinematic =** no significant differences **Kinetic** = no significant differences **EMG** = increased in left thoracic erector spinae for both tasks independent of lifting direction
Marras et al., 2001	Two trials with symmetrical lifting of four weights (4.5 kg, 6.8 kg, 9.1 kg and 11.4kg) form six lift origins; shoulder height, waist height, knee height, mid-shin height (moment arm = 30.5 cm), waist height and knee height (moment arm = 61 cm), ending upright with weight at elbow height with self-selected pace.	**Kinematic** = sagittal trunk position and velocity **Kinetic** = lateral and anteroposterior shear force and compression **EMG** = Both sides of erector spinae, latissimus dorsi, rectus abdominis, external- and internal oblique. Muscle coactivity index.	**Kinematic =** Significant reduction in sagittal position and velocity for trunk and hip lifting farther away and from lower origin **Kinetic =** Significantly increased cumulative lumbar compression **EMG =** Significantly increased muscle activation in all 10 muscles. Greater coactivity index (0.32 versus 0.20).
Pranata et al., 2018	Standing with arms crossed on two "Wii Balance Board" with 8 kg kettlebell between feet. Two trials of lifting to the height of abdomen at self-selected pace and technique.	**Kinematic** = MARP and DP **Kinetic** = lumbar, hip and knee velocity (˚/s)	**Kinematic** = no significant difference for lumbar-hip MARP. LBP_{high} demonstrated significantly less hip-knee DP. **Kinetic** = no significant difference in angular velocities. Significant increased total lifting time (LBP_{high}: 0.94 s, LBP_{low}: 0.74 s).

Table 2 (continued)

Saraceni et al., 2021	100 lifts from the ground: 25 lifts with an empty box (200 g) followed by 75 lifts with box at 10% of BW. Symmetrical and asymmetrical lifts at self-selected pace and technique.	**Kinematic** = lumbar and lumbo- pelvic flexion, thorax inclination, hip- and knee flexion **Kinetic** = peak and average lumbo-pelvic and thorax velocities, compression, shear force, power, net moment, and external forces at S5/L1 joint	**Kinematic** = increased vertical inclined thorax and pelvis, decreased intra lumbar flexion for the beginning of the lifting task **Kinetic** = decreased peak and average thorax and lumbar bending velocities
Sung et al., 2013	Five trials of squatting holding a 2 kg load at arm's length standing on force plate with self-selected pace.	**Kinematic** = hip flexion angle and angular displacements of lumbar spine	**Kinematic** = decreased lumbar spine flexion and increased sagittal hip flexion
Yang, 2018	Three static stoop lifts at three loads: 0%, 10% and 20% of BW. Holding posture for 5 seconds allowing measurement of muscle activity.	**EMG** = External oblique, internal oblique and lumbar multifidus	**EMG =** significantly increased for external- and internal oblique (10% of BW compared to 0%) and increased for remaining loads. Both groups had significantly increased muscle activity for lumbar multifidus (10% of BW, compared to 0%), and increased for remaining loads.

EMG: electromyography, BW: bodyweight, MARP: Mean Absolute Relative Phase, DP: Deviation Phase

3.3 Kinematic differences

Several studies report various results regarding kinematic differences between groups during lifting tasks. Sung (2013) observed increased hip flexion and decreased lumbar flexion among individuals with LBP compared to asymptomatic counterparts during squat lifting, contrary to findings in two other studies (Marras et al., 2001; Saraceni et al., 2021). Marras et al. (2001) reported a reduction in sagittal position for lifting weights placed farther away from the subject and at a lower origin, and Saraceni et al. (2021) found that LBP individuals lifted with a more vertically inclined thorax and pelvis. Furthermore, Saraceni et al. (2021) reported similar results as Sung (2013) with LBP individuals exhibiting decreased lumbar flexion. Notably, the group difference in Saraceni et al. (2021) was statistically significant only for the beginning of the lifting task (1/100 lifts). Two studies (Dideriksen et al., 2014; Pranata et al., 2018) highlighted differences in the randomization and variation of kinematic lifting patterns between groups. Pranata et al. (2018) found that LBP_{high} had less variation in their lifts compared to controls. Dideriksen et al. (2014) reported that non-task related movements were less random among LBP individuals. Lastly, Larivière et al. (2002) found no significant difference in kinematics, and Dideriksen et al. (2014) found no significant difference in task-related angles.

3.4 Kinetic differences

Four studies identified kinetic differences between LBP individuals and controls, whereas two others did not find differences between groups. Saraceni et al. (2021) and Marras et al. (2001) noted decreased velocities (deg/s), indicating that LBP individuals lifted more slowly compared to controls. Saraceni et al. (2021) found decreased thorax- and lumbar bending velocities, but only decreased lumbar peak bending velocities persisting throughout the lifting task. Marras et al. (2001) observed that LBP individuals lifting objects located farther away from a lower origin resulted in a reduction in sagittal velocity compared to controls. Other kinetic variables such as lumbar shear force found in these two studies will not be assessed in this review, due to lack of comparability. Ferguson et al. (2004) found that sagittal peak position occurred significantly later compared to controls. Notably, Pranata et al. (2018) found increased total lifting time for both LBP-groups compared to controls, without significant difference in angular velocities. Conversely, two studies (Larivière et al., 2000, 2002) found no significant difference in various measured kinetics variables, where velocity of the truncus was not measured for one of these studies (Larivière et al., 2000).

3.5 Differences in muscle activity

Four studies reported significant differences with increased muscle activity among LBP individuals across various muscle groups compared to controls. Marras et al. (2001) observed greater muscle activation for erector spinae (ES), latissimus dorsi (LD) and multiple abdominal muscles. Yang (2018) found greater activation for external- and internal obliques (EO, IO). Two other studies (Larivière et al., 2000, 2002) only reported increased muscle activation in the left thoracic ES, even though one of these studies (Larivière et al., 2000) measured almost the identical muscles and muscle areas as Marras et al. (2001). Lastly, Marras et al. (2001) identified a greater coactivity index, indicating that LBP individuals activate antagonist muscles to a larger extent compared to controls. The findings across these four studies present an increased muscle activity among LBP individuals compared to controls.

4. Discussion

The aim of this review was to present and investigate kinematic, kinetic and electromyographical differences between individuals with and without LBP when lifting. The key findings in this study were inconclusive kinematic differences regarding the vertical position of the truncus, with two studies indicating less movement variation among LBP individuals. Most of included studies found kinetic differences with decreased velocity and lifting time, and all studies that measured muscle activity found increased muscle activity for LBP individuals. Firstly, the kinematic trunk- and hip angles, and altered movement patterns will be discussed. Thereafter, the kinetic differences of lifting time and velocity will be discussed. Lastly, the differences regarding increased muscle activation between groups will be discussed, before investigating psychosocial aspects of LBP.

4.1 Kinematic differences between groups

4.1.1 Differences regarding trunk- and hip angles

Several studies present conflicting differences between LBP individuals and controls regarding sagittal flexion of the truncus, in form of different hip- and trunk angles. The increased hip flexion found in Sung (2013) are somewhat contradictory to the reduction in sagittal position found in Marras et al. (2001), and vertical increase of thorax and pelvis found in Saraceni et al. (2021). However, the mean difference for this increased hip flexion is rather small, between 6 and 7 degrees compared to controls. Furthermore, both Saraceni et al. (2021) and Sung (2013) interestingly found similar results with LBP individuals exhibit significantly decreased lumbar flexion at -4.9 deg ($p = 0.002$) and -3.48 deg ($p = 0.03$), respectively. Exhibiting a decrease in lumbar flexion could suggest a more vertical inclined truncus and a possible decreased hip flexion, bringing the body to a more “upright” vertical position. Kinematic differences between groups regarding hip- and trunk angles are conflicting, but somewhat questions the increased hip flexion found in Sung (2013) among LBP individuals when lifting.

The differences in lifting tasks performed between studies could explain conflicting kinematic results. Participants in Saraceni et al. (2021) and Marras et al. (2001) were not instructed to squat and hold a 2 kg weight at arm's length, as in Sung (2013). Holding a 2 kg weight in front of the body at arm's length while squatting compared to lifting a box from the ground, as performed in Saraceni et al. (2021), produce larger moment because of the increased distance to the weight. Larger moment could increase the amount of hip flexion and forward bending, increasing muscular demands. However, the lifting conditions in Marras et al. (2001) included lifts with a moment arm at 61 cm, comparable to an "arm's length" in Sung (2013). The outcome of these lifts was a significant reduction in sagittal position (Marras et al., 2001), even though this study fails to present the exact values for the reduction which is a weakness of this study. To summarize, even though increased hip flexion was found, the findings of two studies (Marras et al., 2001; Saraceni et al., 2021) could lead to the conclusion that LBP individuals possibly lift with a more vertical positioning of the truncus compared to controls.

4.1.2 An altered movement pattern

LBP individuals could exhibit altered movement patterns compared to controls when lifting. Two studies (Dideriksen et al., 2014; Pranata et al., 2018) presented findings regarding the variation of movement patterns in different ways. Similarly, both studies computed and utilized advanced variables (MARP, DP, %DET) trying to explain differences in movement variation patterns for a lifting task. Lumbar-hip MARP was statistically significantly higher between LBP-subgroups (LBP_{low}, LBP_{high}) but not compared to controls (Pranata et al., 2018), therefore not to be discussed. Pranata et al. (2018) did find a significant ($p = 0.026$) difference with LBP_{high} demonstrating significantly less hip-knee coordination variability (DP) compared to controls (0.03 ± 0.03 and 0.14 ± 0.03, respectively). This indicates less variation for this segment couple, substantiating that LBP individuals have altered movement patterns with less variation compared to controls. Furthermore, the significantly ($p < 0.05$) increased %DET present among LBP individuals compared to controls (Dideriksen et al., 2014), does not necessarily support the findings in Pranata et al. (2018). This is because the increase was only significant for non-task related angles (8/12 sensors), even though multiple sensors (7/12 sensors) for task-related angles were increased compared to controls with only one sensor producing statistically significant values ($p = 0.048$). In total, these results further suggest that LBP individuals move less randomly, particularly for non-task-related movement, but probably also for task-related movements. In conclusion, two studies (Dideriksen et al., 2014; Pranata et al., 2018) imply that LBP individuals have altered movement patterns with less variation compared to controls.

4.2 Kinetic differences between groups

4.2.1 Velocity

Most studies indicate that individuals with LBP lift with decreased velocities compared to controls, computed by different variables. Two studies (Marras et al., 2001; Saraceni et al., 2021) that measured velocity (deg/s) implied that LBP individuals lift at a slower pace compared to controls, where one study (Larivière et al., 2002) found no significant difference in velocity (deg/s). Two other studies (Ferguson et al., 2004; Pranata et al., 2018) also indicate that LBP individuals lift with decreased pace, but not derived by angular velocity. Interestingly, Pranata et al. (2018) found significantly increased total lift time with almost 1s longer lift times for both LBP-groups compared to controls (high: + 0.94s: $p = 0.001$, low: + 0.74s: $p = 0.003$), without finding significant difference for specific angular velocities (deg/s) for lumbar, hip and knee. Even though all angular velocities were increased without statistical significance. This study supports the notion that LBP individuals lift slower compared to controls, without statistically significantly differences in angular velocities. Ferguson et al. (2004) partly support LBP individuals lifting slower with peak sagittal positions occurring at a statistically significant later time compared to controls. Ferguson et al. (2004) does not present any findings either for angular velocity (deg/s) or for total lifting time as measured in previous mentioned studies. Therefore, the findings in Ferguson et al. (2004) are unable to describe differences of the pacing utilized between group. However, the findings in this study could indicate that LBP individuals used a longer time for the “initiating phase” of the lift only, until reaching peak sagittal position. In conclusion, four studies (Ferguson et al., 2004; Marras et al., 2001; Pranata et al., 2018; Saraceni et al., 2021) points to LBP individuals lifting slower, computed by different variables. Possible reasons for this could be that LBP individuals reduce lifting paces consequential of experiencing LBP, and as an effort to reduce forces involved.

4.3 Differences regarding muscle activity

4.3.1 Increased muscle activity

Individuals with LBP have increased muscle activity when lifting compared to controls. There is a high level of agreement that individuals with LBP have an increased muscle activity for at least ES, but also for EO and IO, compared to controls (Larivière et al., 2000, 2002; Marras et al., 2001; Yang, 2018). Increased muscle activity could be related to the altered movement patterns present among LBP individuals, exhibiting less variation and decreased lifting paces, as previously discussed. Less random movement among individuals with LBP can indicate that they utilize more of the same muscles each lift and more predetermined movement strategies. This could result in fewer muscles (such as ES) needing to compensate, resulting in increased muscle activity for ES. Whereas controls possibly engage a wider range of muscles, distributing the load more evenly, potentially leading to reduced amplitudes. In short, a greater muscle activation is present among individuals with LBP and probably linked to altered movement patterns when lifting.

The measurement of similar muscles areas across two studies (Larivière et al., 2000; Marras et al., 2001) curiously gave conflicting results. Larivière et al. (2000) distinguishes itself among the included studies by measuring muscle activity of various muscles, but only finding significant ($p = 0.04$) increased muscle activity for left thoracic ES among LBP individuals. Interestingly, Marras et al. (2001) measured almost the exact same muscles and found significant ($p < 0.05$) increase across all muscles measured. The reason for these conflicting results could be explained by the differences in the lifting tasks. Increased muscular and coordinative demands could occur when lifting various weights from various vertical positions (Marras et al., 2001) compared to a full sagittal flexion/extension (Larivière et al., 2000). Furthermore, the variation in horizontal distance could also give reasons for conflicting results between these two studies. Various moment arms in Marras et al. (2001), could justify why this study found increased muscle activity for LD where the other study did not (Larivière et al., 2000). The increased horizontal distance to the weight enables horizontal movement possibly facilitating more muscle activation for LD compared to sagittal flexion/extension with straight elbows performed in Larivière et al. (2000). In summary, the different lifting tasks in these studies (Larivière et al., 2000; Marras et al., 2001) could explain conflicting results.

4.4 Psychosocial factors

Psychosocial factors are not assessed in this review but are highly relevant factors for LBP (Clays et al., 2007; Corrêa et al., 2022; Hadler, 1997). It is likely that exhibiting pain affect the way individuals move and lift and could explain the presented differences exhibited by LBP individuals. Moreover, biomechanical factors and lift times could be specific to pain levels. The findings by Pranata and colleagues (2018) regarding longer lift times in the LBP_{high}-group versus the LBP_{low}-group, arguably substantiate such a relationship. Both increased muscle activity exhibited by LBP individuals found in (Larivière et al., 2000, 2002; Marras et al., 2001; Yang, 2018) and reduced velocities presented by (Marras et al., 2001; Saraceni et al., 2021) could be attributed to pain-altered behaviors. Intuitively, it makes sense to adopt strategies aimed at reducing loads in perceived pain affected joints and tissues, and coping mechanisms on this premise would seem reasonable. However, the effects of adopting such coping mechanisms are not fully understood, and could potentially have counterproductive implications, such as the presented results of higher co-activation (Marras et al., 2001) possibly facilitative of higher compression forces in the LBP-group. Furthermore, LBP individuals lifting with a more vertically inclined trunk (Marras et al., 2001; Saraceni et al., 2021) may have been influenced to do so, by perceptions of "correct" lifting techniques commonly held by the public and healthcare professionals.

4.5 Strength and limitations

Using the presented study-methodology, we cannot differentiate between and determine if the biomechanical difference exhibited by LBP individuals are facilitative of LBP, or a consequence of LBP, or a potential combination. Inclusion criteria originally included LBP subgroups to be age-, gender- and weight-matched, but was altered due to a lack in number of studies meeting the inclusion criteria, which could confoundedly influence results. Biomechanical data was captured by various analysis systems with different measurement devices processed in various software. This makes direct comparisons for different computed variables between studies difficult. The definition of chronic LBP varied among studies included. Inclusion criteria for the LBP-subgroup significantly varied in two studies (Saraceni et al., 2021; Sung, 2013) regarding how lifting was related to the LBP (lifting did not increase acute pain, conversely to lifting being primary aggravator), rendering valid comparisons of results difficult. Time between lifting tasks varied among studies or was not defined and a few studies also used cadences. Several studies defined pain thresholds as inclusion and exclusion criteria, but others did not base subgroups on these criteria. Quantification of pain and disability, and subsequently assessing and sorting subgroups by such quantification thresholds are important if biomechanical differences specific to pain levels are to be addressed.

5. Conclusion

This narrative review found evidence for individuals with LBP exhibiting altered movement patterns when lifting in a majority of the included studies, demonstrating decreased velocity and increased muscle activity. Kinematic differences were in several studies difficult to compare because of various methodology for computed variables, but a possible tendency of LBP individuals moving less random were present. The most consistent findings for kinetic differences were a decreased velocity among LBP individuals compared to controls, with differences deriving from various variables explaining velocity. All studies found increased muscle activity in LBP individuals, but in different muscles and muscle areas, likely influenced by the varying study interventions. It is unclear whether these alterations facilitate LBP or are a consequence of LBP, although experiencing pain likely influences movement and pain induced alterations could be adaptive or maladaptive.

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