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Voluntary step execution in patients with knee osteoarthritis: Symptomatic vs. non-symptomatic legs

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ABSTRACT

Background: Individuals with osteoarthritis fall at a greater rate than the general population, likely as a result of weakness, pain, movement limitations, and a decline in balance. Due to the high prevalence of osteoarthritis in the population, understanding the mechanisms leading to greater fall risk is an important issue to better understand.
Research question: What is the influence of unilateral knee osteoarthritis on the characteristics of performing a voluntary step (i.e., similar to that performed to avoid a fall after a perturbation), compared to healthy age-matched controls?
Methods: Case-control study performed in a Health maintenance organization physical therapy clinic. The research group consisted of a referred sample of 21 patients with unilateral knee osteoarthritis. The control group consisted of 22 age-matched healthy individuals. All participants were over 65 years of age. Participants were excluded if they had a surgical procedure to back or lower limb within one year before testing, oncological or neurological disease or a deficit in tactile sense. Movements were performed with and without dual tasking.
Measurements: Duration of the initiation phase (cue to step initiation), preparatory phase (step initiation to foot off) and swing phase (foot off to foot contact).
Results: In the preparatory phase and swing phase, the osteoarthritis group moved more slowly than the control group, and these differences were larger for forward compared to backward movements. Dual-tasking slowed responses in the pre-movement initiation stage across groups.
Significance: The differences in basic parameters, and the slower movements in the osteoarthritis group, are consistent with known features of osteoarthritis, being a disease commonly regarded as primarily "mechanical", and are likely to increase fall risk. These response deficits suggest we should take advantage of advanced rehabilitation techniques, including cognitive loading, to help prevent falls in older adults with osteoarthritis.

1. Introduction

Falls are a common cause of injury and death among older adults, with 20 % of incidents ending in serious injury (fracture or traumatic brain injury) requiring hospitalization, adding up to an annual treatment cost of 31–34 billion dollars in the US [1]. Thirty percent of people over 65 and fifty percent of those over 80 will fall in a given year. Risk factors for falls include age, functional limitations [2], sensory impairment [3], cognitive decline [4], and chronic diseases that are neurologic or musculoskeletal in nature [5].

Osteoarthritis (OA) is the most common degenerative joint disease with 55 % of men and 67 % of women over the age of 50 diagnosed [6]. OA is typically bilateral, for example, for OA of the knee, approximately 13 % show unilateral knee OA compared to 87 % for bilateral knee OA [7]. OA patients demonstrate many typical features such as muscle weakness, pain and movement limitations, a decline in balance [8,9], deterioration in gait parameters, and a reduction in functional abilities [2] related to the severity of symptoms [10]. OA patients fall at a greater rate than the population of the same age - as much as 50 % compared to 30 % in a non-OA population [11].

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The pain involved in degenerative joint diseases such as OA affects the mobility of these patients. Patients experiencing joint pain report and show problems with balance, swaying more than controls [9], whereas reduction of pain levels reduces the propensity for tripping on an obstacle [12]. Being exposed to chronic pain has cognitive implications as well. For example, attention is compromised in chronic musculoskeletal and joint diseases [13]. These deficits can be problematic when a patient with OA needs to perform a quick change of base of support (e.g. following a perturbation such as tripping on a broken sidewalk). As a result of impaired sensory, integrative, and motor difficulties, which can result in not producing an effective movement pattern, one might not react effectively in order to avoid a fall.

The speed of producing such a voluntary step (i.e., similar to the quick step made to avoid a fall after a perturbation) was tested and found to be of value in general in identifying fallers vs. non fallers, with the difference between the two populations observed when a cognitive load was added [14]. The negative effect of cognitive load to a movement and its effect on balance and fall has been shown consistently in older populations [15–17]. Also, previous research has shown that the timing in taking a quick voluntary step to change the base of support is affected by both cognitive/central features (e.g. changes in cognitive load) and motor/peripheral features (e.g. weaker muscles) in an older group of patients with hemiparesis [18]. Given that patients with OA suffer from both "central" deficits (likely caused by the pain) and "peripheral" deficits, it is interesting to determine whether these patients present changes in the central and/or peripheral components of the step response.

In the current study we describe the differences in production of a voluntary step (using the voluntary step test [14,19,20]), with and without cognitive loading, between a group of patients diagnosed with unilateral knee OA, and a group of age-matched healthy individuals. Despite the lower prevalence of unilateral knee OA[7], we chose to study this population to allow us to compare within-subjects between stepping with the affected and non-affected leg. We will describe the differences according to the 3 stages of the step: Initiation Phase (IP), Preparatory Phase (PP), and Swing Phase (SP), and show the differences between stepping with the painful and non-painful leg (in the OA group). We hypothesize that OA patients will step slower in the motor stages (PP and SP), that stepping in the motor stages will be slower for the more painful leg in the OA group, and that a cognitive task performed simultaneously will have a greater detrimental effect (i.e., a longer duration of the initiation phase (IP)) on the OA group in this more cognitive phase (IP). We included stepping direction as an additional factor, to enable comparisons with previous studies.

2. Methods

2.1. Design

The study was a case-control study.

2.2. Participants

Forty-three participants volunteered (20 women), recruited from a physical therapy clinic in the Or-Yehuda Meuhedet facility during February to November 2016. Patients were recruited sequentially by the physiotherapists or the orthopedic doctor working in a nearby clinic who satisfied the inclusion and exclusion criteria and were willing to participate. Participants in the control group came to the clinic for a wide variety of reasons, but none of them demonstrated symptoms related to the back or lower limb. Two declined.

2.3. Inclusion criteria

For the OA group: Over 65 years of age complaining of pain in one knee. Diagnosis of OA according to American College of Rheumatology [21], i.e. knee pain, presence of osteophytes, plus one of age > 50 years, < 30 min of morning stiffness or crepitus. For the control group: the same age requirements.

2.4. Exclusion criteria

No surgical procedure to back or lower limb within one year before testing. No oncological or neurologic disease or deficit in tactile sense (as measured by light touch with the hand on the skin of the lower limb – thigh, knee, shank, and foot [22]). For the control group: no complaints of knee pain in the past year.

2.5. Experimental protocol

Testing was performed by a single tester. All participants provided written informed consent in accordance with procedures of the Israeli Ministry of Health, and the study received approval from the human ethics committee of Tel Aviv University and the Meuhedet health services (protocol number 02−20-05−15).

After being identified, receiving explanation and providing written informed consent, participants performed several tests. First, the Visual Analogue Scale (VAS) as an average of their pain level in the past week (marking on a scale where the lower end was no pain, and the upper end was the worst pain imaginable, translated linearly into number from 0 to 10) was performed to confirm participants in the control group had no or only mild knee pain (defined as a score less than 3/10 [23]). The Western Ontario and McMaster Universities Arthritis Index (WOMAC) [24] translated to Hebrew [25] to evaluate pain, stiffness and function was scored using the VAS method [26], where scores range from 0−2400. The Mini mental state examination (MMSE) was performed for evaluation of cognitive deficits [27]. Afterwards, participants continued with Five Times Sit To Stand (FTSTS) test as a proxy for lower limb functional strength [28], although it should be noted that FTSTS are strongly influenced by dynamic balance and other factors [29,30]. They also performed the Mini-BESTest (best score is 28) to evaluate balance systems function, which includes the Timed Up and Go Test in single and dual task modes [32,31].

2.6. Voluntary step test procedure

We used a BT4 portable force plate (HUR Labs Finland), which recorded vertical ground reaction force (1D) and computed center of pressure (CoP) at 200 Hz. Three meters in front of it on a computer screen was displayed a letter "X" in the single task mode, or the Stroop Test [32], described in more detail in the supplementary materials, for the dual task mode.

Data from the force plate were analyzed using custom Matlab (Matlab R2016b, Mathworks, Natick, MA, USA) code, available online [33].

Participants were instructed to stand on the force plate and perform a step from it, with a designated foot, onto a platform of the same height, placed in the instructed direction (see Fig. 1(a)). Full details of the instructions are presented in the supplementary material.

The time for performing the trial was divided into three sections: Initiation Phase (IP), Preparatory Phase (PP), and Swing Phase (SP) (see Fig. 1(b)), described in full detail in the supplementary methods. PP was chosen as the primary outcome measure due to the complexity needed to quickly shift the body weight, which we assumed would be challenging for OA patients.

2.7. Statistical analysis

To evaluate between group differences, t-tests were used for normally distributed variables, Mann-Whitney tests for non-normally distributed variables, and chi-squared test for categorical variables. Variables were determined to be non-normal if the skew or kurtosis was

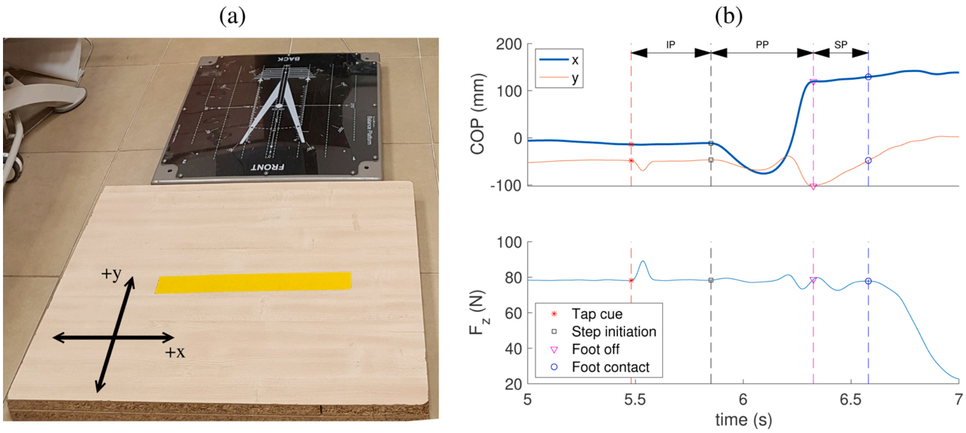

Fig. 1. (a) Experimental setup: the participants started with both feet on the force plate and were instructed to step with a particular foot in the given direction (onto the wooden board) following the cue. The picture shows the setup for a step forward onto the board. Positive axes directions are indicated. (b) An example of calculation of the four time points (tap cue, step initiation, foot off, foot contact) from the force plate data (CoP and ground reaction force F_z), and the three derived measures (Initiation Phase (IP), Preparatory Phase (PP) and Swing Phase (SP)).

significantly different from zero (i.e. z-scores less than -1.96 or greater than 1.96 [34]), and non-normal variables were identified in the text. We used a mixed design Analysis of Variance (ANOVA) to evaluate the influence of the 2 within-subject repeated measures (stepping direction and cognitive loading), on the 2 groups (OA and control). Additionally, we tested the effect of the painful leg (together with stepping direction and cognitive loading) only for the OA group. Post-hoc t-tests were used for analyzing the interactions, with Bonferroni corrections - as there were two tests for each interaction, a p value of less than 0.025 was considered significant. Statistical significance was set at $p < 0.05$ and analysis was performed with SPSS Statistics version 20 (IBM Corporation, USA).

2.8. Sample size

In a previous study [19], the primary outcome measure was distributed normally with a standard deviation of 150 ms. In this research, in order to show a statistically significant difference between group averages of 150 ms, we required 16 participants in each group with a power of 0.8. Likelihood for type one error with this assumption is 0.05 [35]. We collected slightly more than this number (21 or 22 per group) to avoid issues in data analysis.

3. Results

3.1. Between groups differences

The demographic information and results of the functional tests are summarized in Table 1. The OA and control groups were not significantly different in age, weight, height, cognitive status (according to MMSE), or dynamic stability (according to Mini-BESTest). In the five times sit to stand (FTSTS), the OA group was almost 3 s slower, and reported significantly more pain on the VAS, compared to the control group. The OA group was slower for the Timed Up and Go, with and without a cognitive task, compared to the control group. WOMAC results showed higher pain, stiffness, and functional disability scores in the OA group, compared to the control group.

3.2. Step test results

The results are summarized in Table 2, together with the significant differences in the performance of the step test, i.e. the mixed design ANOVA results. Table 3 contains the results comparing painful vs. non-painful leg for only the OA group, and the results of the repeated measures ANOVA. In the following section, we analyze in more detail only the main effects and interactions, non-significant effects are not described.

The OA group performed slower in the step test compared to control group, in the movement related phases: PP (413 ± 84 ms vs. 346 ± 43 ms) and SP (210 ± 42 ms vs. 183 ± 34 ms), see Fig. 2(a).

Overall (i.e. both groups combined), during IP and SP, the backwards step times (IP: 201 ± 35 ms; SP: 179 ± 50 ms) were significantly faster than forward step times (IP: 241 ± 53 ms; SP: 214 ± 46 ms).

A significant interaction of group and direction was observed only for PP, see Fig. 2(b). The OA group showed a faster time for backward movements (399 ± 75 ms) than forward movements (427 ± 96 ms, $t(20) = 3.394$, $p = 0.003$), while the control group showed no difference (backward = 348 ± 50 ms, forward = 345 ± 49 ms, $t(21) = 0.370$, $p = 0.7155$).

A main effect of cognitive load was observed in IP and PP phases, with dual tasks (IP: 262 ± 64 ms, PP: 387 ± 76 ms) taking longer than single tasks (IP: 180 ± 28 ms, PP: 370 ± 78 ms). The predicted interaction between group and cognitive load was not observed for any of the phases.

An interaction was observed between direction and cognitive load only for IP, see Fig. 2(c). Backward movements were faster for the dual task (backward: 225 ± 49 ms, forward: 298 ± 96 ms, $t(42)$=-48.8, $p < 0.001$), but not for the single task (backward: 177 ± 30 ms, forward: 183 ± 35 ms, $t(42) = 4.1$, $p = 0.251$).

The painful leg was compared to the non-painful leg only for the OA group (see Table 3). No main effect was observed for any of the three phases, nor significant interactions with direction or cognitive load.

Table 1
Demographic and test data for OA and control groups.

Variable	Control (N = 22)	OA (N = 21)	P value
BMI*	24.7 (22.6–26.3)	25.3 (24.2–26.7)	0.52
Sex (male/female)*	11/11 (50 %)	12 / 9 (43 %)	0.639
Age (years)	71.95 (5.23)	70.4 (4.4)	0.307
Weight (kg)	70.2 (9.9)	71.9 (10.6)	0.594
Height (cm)	169 (8)	169 (8)	0.903
FTSTS (s)	9.3 (2.4)	12.2 (3.6)	0.004
VAS	0.8 (1.2)	5.5 (2.4)	<0.001
TUG*(sec)	5.8 (5.1–6.1)	7.0 (6.0–8.0)	0.001
TUG DT*(sec)	6.5 (5.5–7.0)	8.7 (7.0–10.7)	0.002
WOMAC*	102 (22–183)	789 (279–1200)	<0.01
Minibest*	26 (23–27)	23 (22–25)	0.061
MMSE*	30 (30–30)	30 (29–30)	0.06

Average (standard deviation) for normally distributed data, median (first - third quartile) for non-normally distributed data, sex is male/female (% female). Non-normal distributions are marked by *. T-tests were used to compare the normally distributed values, the Mann-Whitney test for the non-normally distributed variables, and the chi-squared test for the sex. FTSTS is Five Times Sit To Stand test, VAS is the visual analog scale, TUG is the Timed Up and Go test, TUG DT is the dual task TUG. WOMAC is the Western Ontario and McMaster Universities Arthritis Index, MMSE is the Mini Mental State examination. The significance (p value) level for the comparisons was 0.05.

Table 2
Durations of the phases in the two groups (Control: N = 22, and OA: N = 21).

		Initiation phase (ms)		Preparatory phase (ms)		Swing phase (ms)		Total step time (ms)	
		Control	OA	Control	OA	Control	OA	Control	OA
Backward	Single task	168 ± 22	187 ± 34	342 ± 48	387 ± 78	168 ± 57	196 ± 65	509 ± 97	583 ± 122
	Dual task	220 ± 48	230 ± 51	355 ± 59	410 ± 88	162 ± 45	193 ± 58	517 ± 91	603 ± 127
Forward	Single task	169 ± 22	197 ± 40	330 ± 57	426 ± 105	208 ± 52	224 ± 57	538 ± 85	650 ± 146
	Dual task	287 ± 93	310 ± 100	359 ± 56	428 ± 95	196 ± 33	228 ± 70	555 ± 63	656 ± 134
Group		F(1, 41) = 2.88, p = 0.097		F(1, 41) = 10.77, **p = 0.002** **Control < OA**		F(1, 41) = 5.25, **p = 0.027** **Control < OA**			
Direction		F(1, 41) = 37.91, **p < 0.001** **Backward < forward**		F(1, 41) = 3.39, p = 0.073		F(1, 41) = 18.26, p < 0.001 **Backward < forward**			
Direction * group		F(1, 41) = 0.84, p = 0.365		F(1, 41) = 5.83, **p = 0.020** **OA: backward < forward** **Control: no difference**		F(1, 41) = 0.14, p = 0.711			
Cognitive demand		F(1,41) = 75.87, **p < 0.001** **Single task < Dual task**		F(1,41) = 5.60, **p = 0.023** **Single task < Dual task**		F(1,41) = 0.49, **p = 0.489**			
Cognitive demand * group		F(1,41) = 0.14, p = 0.714		F(1,41) = 0.33, p = 0.569		F(1,41) = 0.53, p = 0.472			
Direction * cognitive demand		F(1,41) = 24.85, **p < 0.001** **Dual task: backward < forward** **Single task: No difference**		F(1,41) = 0.06, p = 0.804		F(1,41) = 0.00, p = 0.991			

The durations of the different phases of the movement for the two groups, for backward and forward movements, and for single and dual task. The upper part of the table shows the mean ± standard deviation for each quantity, while the lower part presents the results of a mixed design ANOVA. Significant differences are shown in bold, and the direction is specified. The significance (p value) level for the ANOVA comparisons was 0.05, and 0.025 for the post-hoc tests (in the interactions).

Table 3
The durations of the different phases of the movement for the OA group, divided into painful and non-painful legs.

		Initiation phase (ms)		Preparatory phase (ms)		Swing phase (ms)		Total step time (ms)	
		Non-painful	Painful	Non-painful	Painful	Non-painful	Painful	Non-painful	Painful
Backward	Single task	184 ± 28	190 ± 47	396 ± 93	378 ± 72	202 ± 90	191 ± 73	598 ± 137	569 ± 125
	Dual task	244 ± 68	216 ± 52	417 ± 102	404 ± 86	184 ± 61	202 ± 69	601 ± 140	606 ± 126
Forward	Single task	196 ± 69	199 ± 43	416 ± 113	435 ± 111	215 ± 72	234 ± 68	631 ± 168	668 ± 154
	Dual task	337 ± 146	284 ± 121	439 ± 111	417 ± 91	214 ± 65	242 ± 97	653 ± 152	659 ± 136
Pain		F(1, 20) = 2.413, p=0.136		F(1, 20) = 0.970, p = 0.336		F(1, 20) = 2.368, p=0.140			
Direction * pain		F(1,20) = 0.392, p=0.538		F(1,20) = 0.591, p = 0.451		F(1,20) = 1.301, p = 0.268			
Cognitive demand * pain		F(1,20) = 3.562, p = 0.074		F(1,20) = 1.409, p = 0.249		F(1,20) = 1.202, p = 0.286			

The durations of the different phases of the movement for the OA group, for painful and nonpainful legs, for backward and forward movements, and for single and dual task. The upper part of the table shows the mean ± standard deviation for each quantity, while the lower part presents the results of a repeated measures ANOVA. No significant differences were observed. The significance (p value) level for the ANOVA comparisons was 0.05, and 0.025 for the post-hoc tests (in the interactions).

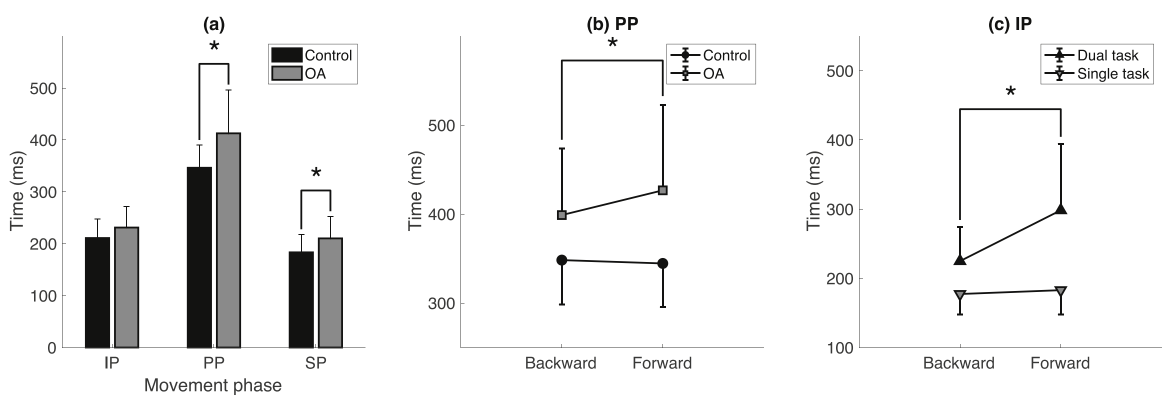

Fig. 2. (a) Time taken to complete the three phases (IP: initiation phase, PP: preparatory phase and SP: swing phase) for the two groups, averaged across direction, cognitive load and leg. The OA group was significantly slower for the PP and SP. (b) Interaction during PP of group and direction: only the OA group were significantly faster for backward compared to forward steps. (c) Interaction during IP of direction and cognitive load: the backward task was significantly faster than the forward task only for the dual task. The graphs show the mean values, bars - standard deviation, * indicates significant differences between groups. The significance (p value) level for the ANOVA comparisons (in part a) was 0.05, and for the post-hoc tests in the interactions (in parts b and c) was 0.025.

4. Discussion

In the current study, we described the differences in the production of the voluntary step test, with and without cognitive loading, between a group of patients with unilateral knee OA, and a group of age matched healthy individuals. We found that, compared to the control group, the OA group moved slower during the more "mechanical stages" (PP and SP) and showed faster backwards than forward movements during PP. In both groups in the dual task conditions during the IP, backward movements were faster than forward movements.

Our hypotheses were that: (1) OA group will perform slower in the motor phases. (2) The OA group will step slower in the motor phases with the more painful leg. (3) Cognitive loading will have a greater effect on OA group. Our first hypothesis was supported: the OA group stepped slower than controls in the PP and SP, the more mechanical parts of the task, suggesting a mechanical manifestation of the differences between the groups. Regarding the second hypothesis, we did not observe a main effect or interaction for stepping with the painful leg in the OA group. Cognitive loading as a main effect produced a difference in IP, and possibly revealed a common difficulty for this age group in the form of limited cognitive resources. However, we did not observe the expected interaction of cognitive loading and group. This is likely because OA does not seem to be correlated with more general cognitive impairment in older adults [36], despite the aforementioned compromised attention observed in OA [13].

The voluntary step was divided into three segments. During the first stage (IP), before they start moving, a main effect of cognitive load (single vs. dual task) was found, as expected for this age group [20]. Significant interactions were also observed between cognitive load and direction (backward vs. forward). The IP is characterized not by movement but by reaction time and central organization for the process of the postural adjustment which precedes the actual change in center of mass (COM), which likely explains why main effects and interactions of cognitive load affected mostly this stage. The interaction with direction highlights the biomechanical asymmetry between forward and backward movements and the likely relationship to the relative difficulty in planning these movements.

In the PP, significant between group differences were found in the timing for the voluntary step, with the OA participants moving slower. The PP stage was chosen as the primary outcome measure, as in this stage there is a need to quickly transfer the COM and generate a movement in the appropriate direction. Older adults diagnosed with OA tend to show more functional limitations [2], and suffer from a higher rate of falls than their healthy age group peers [11]. While the normal aging process commonly deteriorates the function of many systems required for normal and safe movement and stability, older participants diagnosed with OA exhibit other or larger limiting features such as elevated pain levels [37], relevant muscle group weakness [9], fear of falling and deteriorated proprioception [38]. A combination of these features likely contributes to the slower times observed for the OA participants.

In the SP, significant differences were also found between group times, with the OA group moving slower than the control group. The slower performance for the OA group in the PP and SP portions of the movement mirrors the results of the FTSTS test (OA group: 12.2 s vs. control: 9.3 s). This test measures functional expression of lower limb strength (but note other influences, e.g. dynamic balance, sensation [29, 30]), and these results are not surprising as lower limb strength is found to be lower in OA patients [39]. When measuring OA vs. controls during walking, OA patients step slower [40]. It is postulated that reducing speed enables a reduction in joint compressive forces [41].

Stepping backwards was found to be quicker than stepping forward for both groups in the IP and SP phases, and only for the OA group in the PP phase. It may be intuitively sensible to step quickly backwards as we have less sensory abilities and motor experience in that movement direction, thus reducing one-foot weight bearing time in the backwards direction would likely be safer than a longer duration step. This difference may also be partially due to biomechanical factors, such as the feet providing different limits of stability, as observed previously [42]. Adding a cognitive load negatively affected performance times in IP and PP for both groups. This is in line with previous studies that have shown that a cognitive load such as a Stroop task can negatively affect performance in the step test [20].

Between age group differences have been found when comparing healthy young and old groups in voluntary step times [43]. Significant differences were found in IP, where the older group stepped slower in all directions. In SP, differences were significant in the forward direction only. In our experiment, differences between groups were observed in PP and SP phases. We note that all our participants were older, which may explain the lack of difference in the IP phase between groups.

When the dual-task voluntary step was tested in post-stroke participants, step times increased in IP, but also for healthy controls [18]. When comparing step times for affected vs non-affected leg in post-stroke participants in the same paradigm, the two slowed as a result of cognitive load addition, again in IP. This manifestation of "central" vs "peripheral" difficulty might reflect the different characteristics of the two disorders. Cognitive variables relevant to managing and coping with pain (coping, self-efficacy, somatization, pain catastrophizing and helplessness), were found to be moderately inversely correlated with knee pain [44]. Pain is assumed to be a competitor with other attention-demanding tasks, out of a given reserve or resources available [45]. Based on these studies, we would expect that a cognitively demanding task would have a negative effect on step times in a painful limb. However, here we did not observe this effect. This may be because the voluntary step requires knee movement with both legs (both the painful and non-painful sides) including loading the non-stepping leg (which is the painful side when stepping with the non-painful leg), which may have partially explained the group-level differences in the more mechanical parts of the task (PP and SP).

While the number of falls in the last year was not recorded (see study limitations), we can infer fall risk based on the standard tests performed (TUG, FTSTS, Minibest). Although significant differences were not observed for the Minibest, in the other two tests (the TUG and FTSTS) the OA group showed significantly slower times compared to the control group. For the TUG, slower times correspond to a higher fall probability, although none of the subjects in our sample had times slower (greater) than 13.5 s (suggested as the cutoff for high fall risk [32]). For the FTSTS, slower times also correspond to higher fall risk. Five (out of 21) participants in the OA group had times slower than 15 s (suggested as the threshold for higher fall risk [46]). The increased risk for the OA group suggested by these tests corresponds with the slower times observed for this group in the step test, which has previously been shown to predict increased fall rate [19], as well as with other studies showing higher fall risk for individuals with knee OA [47].

4.1. Study limitations

In the control group, we did not use a radiographic evaluation to ensure they did not have OA, however, we can still distinguish them from the OA group because they did not meet the inclusion criterion, i.e. not reporting knee pain [21], defined as a VAS score less than 3/10. Additionally, the control group came to the clinic for non-knee related reasons (for example, neck or shoulder pain) but still require some type of other treatment, thus they are not completely a healthy control group, and may have had other conditions that affect their stepping ability. We also did not record information about the number of falls in the last year, which may have affected their performance. Of the control group, 10 participants had mild knee discomfort (VAS scores greater than 0 but less than 3). They showed significantly lower pain and disability compared to the OA group (see Table 1). This study only looked at individuals with unilateral OA (and not the more common bilateral OA), to allow us to compare more and less painful legs. This may affect the external validity of the findings of this study, although we expect to see similar phenomenon in patients with bilateral OA. In this study, the equipment we used was different than the setup used in previous studies [14,19,20]. As we did not have data for the ground reaction force in the front-back and left-right directions, we adjusted the cue used. Our participants knew beforehand which foot to step with next, but were instructed to stand symmetrically and were corrected when this was not the case.

5. Conclusions

In this study, we demonstrated differences in a voluntary step response in older adults with unilateral knee osteoarthritis compared to an age-matched control group. The OA group was slower in the mechanical phases of the response, i.e. after starting to move. In addition, both groups showed slower responses for forward compared to backwards movements, and slower responses in the pre-movement initiation stage when performing dual-tasking. These longer response times due to OA and dual-tasking likely increase fall risk, and should be considered when developing strategies for reducing falls in this population.

Author contributions

GB, GN, MP, JF designed the experiment, wrote and approved the manuscript, GB ran the experiment, GB and JF performed the data analysis.

Declaration of Competing Interest

The authors have no conflict.

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Everyone who significantly contributed to the project are included as authors on the article, and all authors meet the criteria for authorship. This study was performed as a partial fulfillment for the requirements of the Master of Science in Physical Therapy offered by Sackler Faculty of Medicine, Tel Aviv University. The research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2020.10.006.

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