

CORRELATION OF LUMBAR-HIP KINEMATICS BETWEEN TRUNK FLEXION AND OTHER FUNCTIONAL TASKS



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ABSTRACT

Objective: The purpose of this study was to explore the relationship between the kinematic profiles of flexion of the upper lumbar and lower lumbar (LL) spine and hip and 3 sagittally dominant functional tasks (lifting, stand-to-sit, and sit-to-stand).

Methods: Fifty-three participants were recruited for this study. Four sensors were attached to the skin over the S1, L3, T12, and lateral thigh. Relative angles between adjacent sensors were used to quantify the motion for the hip, LL, and upper lumbar spine. Pearson correlation coefficients were used to explore the relationship between the movements and more functional tasks. One-way analysis of variance was used to determine the significance of differences between the variables.

Results: Flexion resulted in a greater or similar range of motion (ROM) to the other tasks investigated for both spinal regions but less ROM for the hip. Strong correlations for ROM are reported between forward flexion tasks and lifting for the LL spine ($r = 0.83$) and all regions during stand-to-sit and sit-to-stand ($r = 0.70$ - 0.73). No tasks were strongly correlated for velocity ($r = 0.03$ - 0.55).

Conclusion: Strong correlations were only evident for the LL spine ROM between lifting and flexion; all other tasks afforded moderate or weak correlations. This study suggests that sagittal tasks use different lumbar-hip kinematics and place different demands on the lumbar spine and hip. (*J Manipulative Physiol Ther* 2015;38:442-447)

Key Indexing Terms: *Flexion; Lifting; Sitting; Standing; Lumbar; Hip; Correlation; Function; Tasks*

Clinical evaluation of the lumbar-hip complex is commonplace in musculoskeletal therapies such as physical medicine/rehabilitation, chiropractic, osteopathic, and physiotherapy clinics.^{1,2} Traditional texts

advocate the assessment of motion in the cardinal planes. The evaluation of the behavior of the spine and hip during spinal motions such as flexion/extension is a potential test used to observe lumbar impairments.³⁻⁵ Clinicians use the results of motion tests such as forward flexion to aid in the clinical reasoning process when attempting to determine treatment and rehabilitation options.

Disorders of the lumbar-hip complex have been shown to affect lumbar spine and hip range of motion (ROM) as well as the interaction between these 2 anatomical regions.⁵⁻⁷ Moreover, disorders of the lumbar-hip complex have a demonstrably significant effect on movement velocity, both at the hip and at the lumbar spine.⁸⁻¹³ This has been determined for cardinal ROM (lumbar flexion/extension) and in more functional movements such as lifting an object from the floor, a commonly reported daily activity.¹¹ Moreover, sit-to-stand and stand-to-sit are common activities of daily living, which are reportedly completed approximately 60 times a day in certain working populations.¹⁴ These activities are also known to be affected by the presence of disorders of the lumbar-hip complex. This suggests that disorders of the lumbar-hip complex may affect functional tasks as well as the cardinal movements often used in the clinic.

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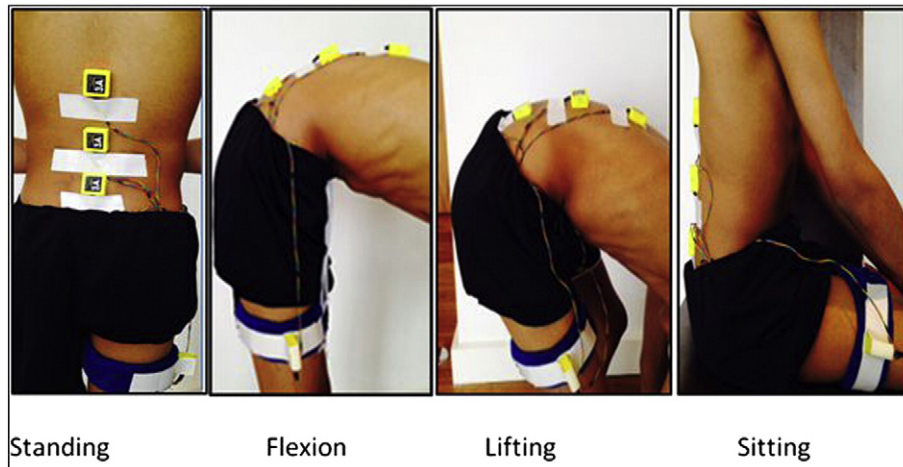


Fig 1. Schematic represents the location of 4 sensors on spinous processes of T12, L3, and S1 and on the lateral aspect of the thigh midway between the lateral epicondyle and greater trochanter on the iliotibial band.

Currently, it is not well understood to what degree the cardinal motions, such as forward flexion, are related to more functional tasks. It is possible that there is no relationship between forward flexion and other sagittally dominant functional tasks, such as lifting, stand-to-sit, or sit-to-stand. If there were no relationship, using forward flexion as a basis for exploring sagittal movement behavior would be flawed, potentially leading to erroneous clinical judgements and reasoning. However, it may be that forward flexion is closely related to other sagittal tasks, making the assessment of many tasks within the clinic unnecessary. Therefore, a better understanding of the relationship between forward flexion and sagittal tasks may aid in the interpretation of clinical assessment and treatment decision making.

The assessment of the spine usually involves the completion of movements in the cardinal planes, and the relationship between these cardinal motions and functional tasks such as lifting, stand-to-sit, and sit-to-stand has yet to be established. Therefore, the purpose of this study was to explore the relationship between the kinematic profiles of trunk flexion and 3 sagittally dominant functional tasks (lifting, stand-to-sit, and sit-to-stand). The kinematic profile for the anatomical regions of upper lumbar (UL) and lower lumbar (LL) spine and hip will be used to determine correlations and differences.

METHODS

Subjects

Fifty-three subjects were recruited from Cardiff University (age, 29.4 ± 6.5 years; mass, 75.3 ± 16.4 kg; height, 1.69 ± 0.15 m). None of the participants had a history of spinal pain or reported any disorder of the cervical, thoracic, or lumbar spine or the hip. Participants were screened to be free from neurologic conditions, vestibular disturbances, inflammatory joint disease, and a history of spinal surgery. This study was

approved by the Cardiff School of Engineering Ethics Committee. Participants were recruited via email advertisement to staff and postgraduate students; thus, our cohort was a convenience-based sample. All participants provided written informed consent.

Instrumentation

A string of 4 accelerometers (3A Sensors; THETAmetrix, Waterlooville, UK) was used to measure the kinematics of the lumbar spine and hip. Each sensor footprint was 24 mm^2 and was connected to a laptop computer via universal serial bus cable. Each sensor provides absolute orientation (tilt) with respect to gravity. Such a system has been shown previously to have excellent repeated-measures reliability relating to spinal motion analysis, with the intraclass correlation coefficient ranging from 0.88 to 0.99 and a standard error of measurement ranging from 0.4° to 5.2° .¹⁵ The accuracy of such a system has been established in a preliminary study and shown to offer root mean square errors of 0.70% to 1.39% compared with a precision angle measurement table (THETAmetrix).

Procedure

Subjects were asked to perform a warm-up exercise, which included flexion, extension, and rotation of the trunk. Four sensors were placed firmly on the skin using double-sided hypoallergenic tape over the spinous processes of T12, L3, and S1 as well as the lateral aspect of the right thigh midway between the lateral epicondyle and greater trochanter on the iliotibial band (Fig 1). Participants were permitted 1 trial of the movements before data collection to familiarize themselves with the procedure and moving with the sensors attached. Participants stood barefoot on assigned markers and focused on a wall marker set at a height of 2 m with arms relaxed by their side. Movements included forward bending, lifting an

Table 1. Mean (SD) ROM and Velocity for the 4 Tasks and Each Anatomical Region

Tasks	ROM (degrees)			Positive Velocity (degrees/s)			Negative Velocity (degrees/s)		
	UL	LL	Hip	UL	LL	Hip	UL	LL	Hip
Flexion	23.3 (10.1)	36.0 (13.3)	53.2 (14.6)	22.4 (8.8)	31.6 (14.1)	33.0 (18.5)	22.2 (9.9)	28.7 (13.6)	35.0 (16.9)
Lifting	21.6 (9.9)	35.4 (13.9)	63.2 (14.6)	25.2 (11.8)	35.6 (13.4)	51.5 (22.4)	23.3 (8.8)	33.4 (14.5)	50.6 (25.3)
Stand-to-sit	17.0 (10.1)	27.0 (14.9)	64.4 (17.3)	16.6 (7.7)	26.7 (15.2)	57.5 (21.3)	10.0 (4.1)	16.3 (9.6)	35.0 (21.5)
Sit-to-stand	16.3 (10.2)	26.6 (14.9)	64.8 (18.4)	9.5 (5.8)	16.4 (10.6)	40.9 (22.2)	17.0 (8.6)	27.5 (15.0)	64.3 (28.4)

LL, lower lumbar; ROM, range of motion; UL, upper lumbar.

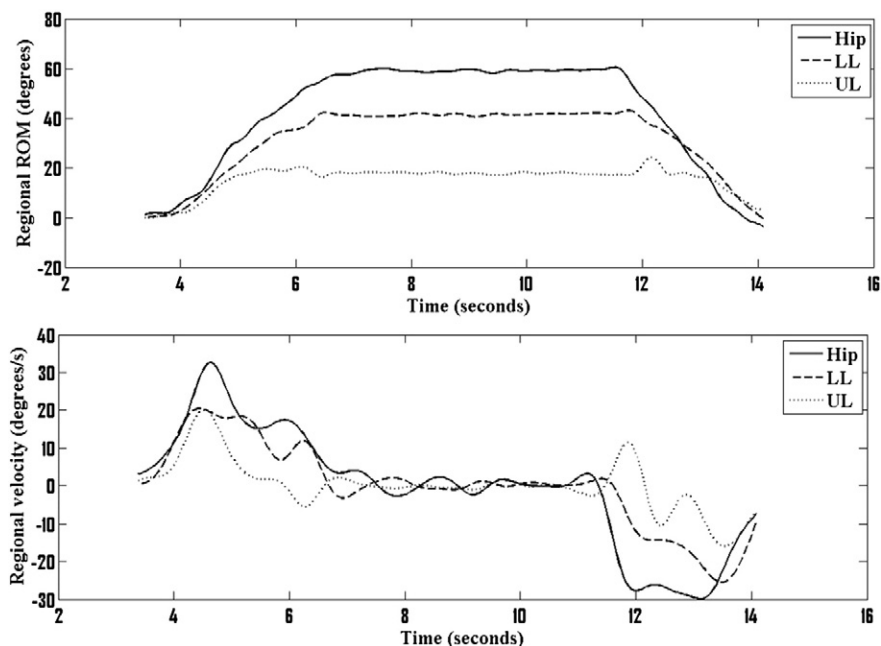


Fig 2. ROM-time and velocity-time graphs of hip, LL, and UL during flexion task of individual participant.

object (ie, wooden box with handles weighing 3 kg) from the floor and returning to a standing position, moving from stand-to-sit on a stool and then returning to standing.

Data Analysis

Data were captured at 30 Hz. Upper lumbar spine kinematics were derived from the relative sagittal angle between the T12 and L3 sensors and LL spine from the relative angle between the L3 and S1 sensors. Hip kinematics were derived from the relative angle between the S1 and thigh sensors. Positive and negative velocity of the upper spine, lower spine, and hip were obtained for all tasks by differentiating the ROM data. All data were normally distributed. Correlations between tasks were explored comparing ROM and velocity profiles using Pearson correlation coefficient calculated in matrix laboratory software (Matlab R2013a, MathWorks, Inc, Natick, MA). One-way analysis of variance was performed using the Statistical Package for the Social Sciences software (Statistics 20, IBM, Armonk, NY) to determine if significant differences are evident between the task kinematics. Post hoc analysis was carried out using the

Tukey procedure to determine the location of any differences. Statistical significance was accepted at the 5% level for all tests.

RESULTS

Mean (SD) ROM across all the tasks for each anatomical region is displayed in Table 1, and a single participant's ROM-time and velocity-time graphs are presented in Figure 2 for the movement of flexion. The ROM used during flexion was significantly different from those for stand-to-sit and sit-to-stand for all anatomical regions. Differences in ROM between flexion and lifting were observed for the hip only (Table 2).

Moderate to good correlations were observed between flexion and lifting for all anatomical regions investigated ($r = 0.57-0.83$). Moderate to good correlations were also evident between flexion and stand-to-sit for all anatomical regions ($r = 0.52-0.70$) as well as for flexion and sit-to-stand ($r = 0.55-0.73$) (Table 3).

Mean (SD) velocity across all tasks for each anatomical region is displayed in Table 1, and the differences between flexion and lifting velocity (positive and negative) were

Table 2. Significant Differences (*P* value) for ROM and Velocity for Each Anatomical Region

		Significant Difference		
		ROM (degrees)	Positive Velocity (degrees/s)	Negative Velocity (degrees/s)
UL flexion	Lifting	.206	.129	.421
	Stand-to-sit	<.001	<.001	<.001
	Sit-to-stand	<.001	<.001	.007
LL flexion	Lifting	.545	.084	.017
	Stand-to-sit	<.001	.063	<.001
	Sit-to-stand	<.001	<.001	.552
Hip flexion	Lifting	<.001	<.001	<.001
	Stand-to-sit	<.001	<.001	.990
	Sit-to-stand	<.001	.039	<.001

LL, lower lumbar; ROM, range of motion; UL, upper lumbar.

evident for the hip and LL spine but not for the UL spine. Differences between flexion and stand-to-sit were observed for positive and negative velocity in the UL spine, as well as differences in negative velocity in the LL spine and positive velocity for the hip (Table 2). Flexion velocity was significantly different from sit-to-stand velocity at the UL spine (positive and negative) as well as for the LL spine (positive velocity) and hip (negative velocity).

Poor to moderate correlations were evident between flexion velocity and lifting velocity for all anatomical regions ($r = 0.25-0.55$), suggesting a limited relationship between the 2 movements. Poor to moderate correlations were also observed between flexion velocity and velocity during stand-to-sit and sit-to-stand ($r = 0.03-0.55$), further suggesting a limited relationship between flexion velocity and velocity used during the other functional tasks.

DISCUSSION

This study explored the relationships between the different sagittal tasks commonly assessed within the clinical environment to determine if the resultant kinematics represent distinctly different movements. This was achieved using a novel sensor string enabling multiple anatomical regions to be studied.

The results show that, on the whole, sagittal kinematics of the hip and lumbar spine during forward flexion tasks are different from those observed during other functional tasks. This finding suggests that the movement of flexion is distinctly unique to the other movements investigated.

It is commonplace for clinicians to assess flexion in a routine clinical examination of the spine; however, these findings suggest that it may be necessary to assess other functional tasks as kinematic inferences about other movements are unlikely to be accurately drawn from assessment of flexion alone.

The results of the study show that there are similarities between flexion and lifting. At both lumbar regions, there was no difference in the ROM; the magnitude of difference

Table 3. Correlation (*r*) for ROM and Velocity for Each Anatomical Region

		Correlation		
		ROM (degrees)	Positive Velocity (degrees/s)	Negative Velocity (degrees/s)
UL flexion vs lifting		0.57	0.25	0.39
UL flexion vs stand-sit		0.52	0.16	0.06
UL flexion vs sit-stand		0.55	0.19	0.03
LL flexion vs lifting		0.83	0.29	0.53
LL flexion vs stand-sit		0.70	0.19	0.29
LL flexion vs sit-stand		0.73	0.28	0.55
Hip flexion vs lifting		0.58	0.47	0.55
Hip flexion vs stand-sit		0.67	0.24	0.31
Hip flexion vs sit-stand		0.66	0.09	0.51

LL, lower lumbar; ROM, range of motion; UL, upper lumbar.

was less than 2°. This suggests that participants used as much spinal flexion during lifting as they did during forward bending. Individuals seemed not to routinely alter their lumbar curvature during low load lifting, a finding observed previously within the literature.^{8,16,17} Range of motion was different at the hip for lifting, where a greater range of hip flexion was used to achieve the lift. This shift in hip contribution did not seem to affect the lumbar spine, suggesting that individuals who use more hip flexion during lifting do not necessarily decrease their lumbar flexion ROM. Velocity demonstrated some distinct differences between the 2 movements for the LL and hip regions. Therefore, despite the ROM being similar, suggesting similar kinematic profiles, it is the higher order kinematics (velocity) where differences exist, demonstrating that lifting resulted in greater velocity at the LL spine and hip. Although this finding has been reported previously, it suggests that providing an individual with a target or focus to the motion seems to result in greater velocity.⁸ This is a factor warranting further exploration but may have implications when interpreting the effects of lifting within the clinical setting.

Correlation, as opposed to testing for difference, explores the relationship between the ROM across the tasks (rather than the difference in ROM for each task), and the results suggest only a moderate relationship in the ROM used. A strong correlation between flexion and lifting was noted for the LL spine, suggesting a good relationship between the magnitudes of motion demonstrated between these 2 motions. This provides further evidence for the similarity in behavior between these motions for the LL region. It is not known whether an alteration in 1 of these movement profiles will directly affect the other and is something for further investigation. Only moderate correlations were noted for the UL and hip regions, providing evidence of a weaker relationship and illustrating a lack of similarity between these tasks for these regions. Therefore, caution is advised if extrapolating flexion kinematics to those of lifting for the UL and hip region.

Stand-to-sit and sit-to-stand appear to use different kinematic profiles for all anatomical regions. Compared

with flexion, less spinal ROM is evident with a greater contribution provided by the hips. These findings are supported by previous studies on both lumbar flexion and sit-to-stand and stand-to-sit.¹¹ Furthermore, this study found a greater contribution from the LL spine during both flexion and sit-to-stand and stand-to-sit. Previous studies have explored the relative motion between the lumbar regions during sit-to-stand only,^{16,18} and therefore, this study expanded the analysis to other functional tasks on lumbar regions and hip.

The inclusion of these functional tasks during clinical assessment will explore the different relationships between the lumbar spine and hip and is likely to provide different information about overall movement behavior of the lumbar-hip region than flexion alone. Self-selected velocity for flexion compared with sit-to-stand and stand-to-sit provides further evidence of the uniqueness of these tasks. Flexion was consistently completed using greater velocity for the spinal regions, compared to sit-to-stand and stand-to-sit, with the opposite being true for the hip. Velocity during flexion seems to poorly correlate with velocity used during other functional tasks, suggesting that each task has distinct properties relating to dynamic movement behavior. The correlations between velocity of different tasks for the lumbar spine and hip have not been previously explored in the literature; therefore, this novel finding provides new insights into the relationship between flexion and other tasks. Velocity has been shown to be a key determinant of movement smoothness and therefore provides important information regarding kinematics.⁸ Therefore, clinically, the interrelationship between hip movement velocity and lumbar velocity cannot be fully explored using flexion alone.

This study suggests that the motion of flexion is unique in its kinematic profile. This suggests that clinicians should not be overreliant on the interpretation of flexion ROM within the clinic to determine the degree of impairment. The results suggest that other sagittal tasks are unique in how they challenge the lumbar spine and hip, and therefore, clinicians should be cautious about inferences made from assessing flexion alone. The failure to assess other movements functionally relevant to the patient is likely to result in an incomplete understanding of the movement profile. An assessment incorporating other functional tasks, even if they are in the same movement plane, may be necessary to better understand the movement behavior of these regions.

Limitations

This study was limited to a young male population. It is not known whether these results would be replicated with other ages or female participants. The population was healthy and therefore serves as a reference for an asymptomatic population¹⁹; however, the extrapolation of

the results to those with pathology or pain may not be possible. This study focused on sagittal movements, as these are common in daily living; however, the relationship between other cardinal plane spinal motions and their functional counterparts is not known.

Further research could extend the analysis to females or differing age groups. It may be possible that, due to age-related changes in the spine, the relationship between cardinal movements and functional movements are altered. Furthermore, a similar method could be used to explore whether treatment-induced gains in ROM (eg, flexion) have any automatic effect on other more functional sagittal tasks.

CONCLUSION

This study suggests that sagittal tasks use different lumbar-hip kinematics and place different demands on the spine and hip. Strong correlations were only evident for the LL spine ROM between lifting and flexion; all other tasks afforded moderate or weak correlations. Significant differences were evident in the ROM and velocity comparing flexion to other sagittal tasks. These findings suggest that clinicians should not extrapolate findings from clinical testing of flexion to other functional tasks, as they demonstrate functionally unique kinematics.

FUNDING SOURCES AND POTENTIAL CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): J.M.W., R.S.A.

Design (planned the methods to generate the results): R.S.A., M.D.J., P.S.T., J.M.W.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): M.D.J., J.M.W., P.S.T.

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Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): J.M.W., M.D.J., P.S.T.

Practical Applications

- The study findings demonstrate that trunk flexion results in a greater or similar ROM to the other tasks investigated for both spinal regions but less ROM for the hip.
- Strong correlations for ROM are reported between flexion and lifting for the LL spine ($R = 0.83$) and all regions during stand-to-sit and sit-to-stand ($R = 0.70-0.73$).
- No tasks were strongly correlated for velocity ($R = 0.03-0.55$).
- Thus, the results show that sagittal kinematics of the hip and lumbar spine during trunk flexion are different from those observed during other functional tasks.
- This finding suggests that the movement of flexion is distinctly unique to the other movements.

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