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Electromyographic evaluation of spine and lower extremity muscles during repeated and sustained bodyweight deep-squat

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Abstract
Introduction. Squat is a preferred exercise included in strengthening and rehabilitation protocols due to its ability to recruit large muscles of the spine and lower extremities. Speed of performing movement and regular practice are known to influence muscle activation. However, muscle activation during fast-repeated bodyweight deep-squat and sustained deep squat remains less explored. Aim of Study. This study aimed at exploring muscle activation during fast and sustained bodyweight squat and observing the effect of habitual squat exposure on spine and lower extremity muscle strength and activation. Material and Methods. Forty healthy adults (30-45 years), with varying daily squat exposure, were recruited for this cross-sectional study following an institutional ethical approval. Superficial electromyography of the erector spinae, rectus abdominis, gluteus maximus, gluteus medius, vastus lateralis, biceps femoris and the gastrocnemius was recorded during a single controlled squat, repeated fast squat and sustained squat. Muscle strength was evaluated using a trunk-leg dynamometer. Results. Higher muscle activity was observed during the ascent phase (81-240% MVC) and the descent phase (76-292% MVC) of a single squat, whereas the sustaining squat demanded low muscle activity (27-58% MVC). Repeated fast squatting elicited 2.5--10 times greater muscle activation than sustained squat. Muscle activity did not vary significantly among people with varying squat exposure. A moderately strong negative correlation was observed between deep squat repetitions and age ($r = -0.710$, $p \leq 0.001$), whereas a moderate positive correlation was observed between deep squat repetitions and force developed during trunk and leg dynamometry ($r = 0.610$, $p < 0.001$, $r = 0.654$, $p < 0.001$, respectively). Substantial co-activation of the erector spinae–rectus abdominis, biceps femoris–vastus lateralis and gluteus maximus–gluteus medius was observed during fast repeated squat. Conclusions. Repeated, dynamic, bodyweight deep-squatting exercises elicited greater muscle activation compared to sustained squat. Exercises over and above habitual activities of daily living involving sustained squatting are essential to obtain greater benefits in muscle strength.

KEYWORDS: electromyography, muscle strength, squat, strength training, physical conditioning.

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Introduction

Squat exercises are an important component of strengthening protocols especially in sports training and musculoskeletal rehabilitation [5, 12, 19, 23, 24]. Deep squat is a triple flexion movement, which moves the hip, knee and ankle joints over an almost full range of motion, simultaneously activating several muscles of the spine and lower extremities [12, 13, 24].

Superficial electromyography (sEMG) is an established, non-invasive, electrophysiological recording technique used to detect electric potential generated due to muscle excitation [30]. Muscle activation patterns during exercises, the level of activation and a comparison against maximum voluntary contraction, enables a comparison of capacity versus performance of an individual during an activity. Based on observations during EMG studies, exercises can be prescribed to enhance activation of specific muscles as well as determine the intensity of activity required to elicit the desired strengthening effect.

Several studies have reported the muscle activation pattern during deep squat. Squat is initiated by the deactivation of the erector spinae to bring about trunk flexion. Further, hip-knee flexion and ankle dorsiflexion are brought about by the activation of the tibialis anterior and hamstring muscles [13, 16]. As the knee flexion progresses, a strong knee extensor activity is generated to counterbalance the external flexor torque and maintain balance. Knee flexion beyond 70º results in an increased muscle activity of the vastus lateralis, gastrocnemius and gluteus maximus [7]. At full depth of squat, the thigh-calf contact results in a reduction of torque [27]. However, biarticular muscles such as hamstrings and quadriceps co-contract to maintain knee stability [21]. Although EMG activity during the eccentric and concentric phase of squat is reported, muscle activity during sustained, bodyweight deep squat and fast repeated, bodyweight deep squat is poorly explored. This information would be particularly useful while prescribing squat exercises to obtain a maximal strengthening effect, using bodyweight, in healthy adults and people with weak spine and lower extremity muscles.

Secondly, people from the Asian and African subcontinents are already habituated to spending a varying duration of time in the deep-squat posture to perform activities of daily living and occupational tasks [14]. Physical activity involving deep squat can serve as a beneficial exercise stimulus inducing physiological adaptation in muscles of lower extremities [20]. It was hypothesized that static-dynamic muscle activations while performing ADL would lend greater muscle strength and muscle activation in people with high squat exposure.

Therefore, the objectives of this study were to explore muscle activation of lower extremities and spine muscles during repeated and sustained deep squat and to identify whether habitual squat exposure leads to differences in muscle activation and strength of spine and lower extremity muscles. The information gained would be useful for prescribing tailor-made squat exercise programs for healthy people and people with movement dysfunctions.

Aim of Study

This study aimed at exploring muscle activation during fast and sustained bodyweight squat and observing the effect of habitual squat exposure on spine and lower extremity muscle strength and activation.

Material and Methods

An observational, cross-sectional, electromyography-based study was undertaken to explore muscle activation during repeated and sustained deep squat. Ethical approval was sought from the Ethical Committee for Research on Human Subjects (MGMIHS/RS/2015--16/190). Participants were tested at the Centre of Human Movement Sciences. Forty healthy adults, not engaged in formal strength training or physical activity programs, were recruited. People with known musculoskeletal, cardiovascular, respiratory, metabolic or neurologic disorders, musculoskeletal injury or pain in the past year or any discomfort that prevented participation were excluded. A written informed consent was obtained from all participants as per the Declaration of Helsinki guidelines.

Participants

Participants were grouped based on squat exposure into non-squatters (people with nil squat exposure, n = 15; 7 male, 8 female) and habitual squatters who were further classified as activity of daily living (ADL) squatters (i.e. people who adopt squatting to perform self-care activities and household chores, n = 14; 7 male, 7 female) and occupational squatters (i.e. people who adopt squatting for occupational tasks and ADL, n = 11; 5 male, 6 female). People with squat exposure for self-care and household chores were classified as ADL squatters, while people with squat exposure for occupational activity in addition to ADL were classified as occupational squatters.

Procedure

Squat exposure was quantified using a reliable and validated tool, i.e. the MGM Ground Level Activity Questionnaire [3]. Habitual physical activity was quantified using the International Physical Activity Questionnaire – Short Form (IPAQ) [9].

Muscle activity was recorded during single squat, repetitive squat, sustained deep squat and maximum voluntary contraction (MVC) using wireless superficial electromyography (sEMG) 8 channel system (Trigno Wireless EMG System; Delsys, Inc., Boston, MA, USA) at a sample rate of 2,000 Hz, with a bandwidth of 20-450 Hz, common mode rejection ratio >80 dB, and noise <0.75 μV. Muscle activity was evaluated on the right side of the body as previous studies have demonstrated that deep squat is a symmetrical activity [22].

Bipolar sensors were placed on the skin over seven muscles, namely the erector spinae, rectus abdominis (as prime movers of the trunk), gluteus maximus, gluteus medius, vastus lateralis, biceps femoris and the medial head of the gastrocnemius (as primary muscles controlling motion at the hip, knee and ankle joints during squat activity) [11]. Electrodes were placed as per SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) recommendations [24]. Following skin preparation by shaving, peeling and cleaning the electrodes were positioned as described by researchers in previous studies [1, 24, 25, 26, 27]. Electrodes were secured with adhesive tape to prevent displacement during exercise.

EMG was recorded while performing a 10-second maximum voluntary contraction (MVC), targeting each muscle using standard methods, in order to normalize and compare muscle activity between the different activities and groups. The sEMG signal of MVC was recorded using functional test positions described previously [5, 6, 18, 19, 20]. Maximum manual resistance was opposed by the researcher in a direction opposite to the motion being tested [4].

Electromyography data from mid-8 seconds of the 10 second MVC were analysed using the EMG analysis software (National Instruments, Austin, TX). Raw EMG data were band-pass filtered at 20 to 450 Hz and smoothed using a root mean square sliding window function with a time constant of 20 milliseconds, window length of 0.125 sec and window overlap of 0.0625 sec. Data was inspected for artifacts and power spectral analysis was performed. Data corrupted with motion artifacts and high signal noise were excluded from the analysis.

Muscle activity was evaluated while participants performed a single deep squat. Participants were requested to keep hands stretched forwards, adopt a comfortable stance, descend to deep squat (150° knee flexion), sustain the position for 5 seconds and ascend to stand.

For evaluation of muscle activity during sustained deep squat, participants were requested to keep hands stretched forwards, adopt a comfortable stance, descend to deep squat, sustain the position for 30 seconds and ascend to stand. Participants were given a 5-minute rest period following the test.

Patterns of muscle activity during fast repetitive squat were evaluated using the 30-second deep-squat test. Participants were instructed to perform as many deep squat repetitions as fast as possible, in a period of 30 seconds. The number of complete squat-stand repetitions was recorded. A higher number of repetitions indicated greater muscle strength-endurance. sEMG was recorded continuously during the test. No participant reported any discomfort during the test. Participants were given a 5-minute rest time following the test.

Muscle strength of lower extremity and trunk muscles was evaluated using a calibrated Back-Leg-Chest Dynamometer (Model SH5007, Saehan Corporation, Korea). The dynamometer measured isometric muscle strength, recorded in kilograms (kg) of force. Vertical upward force was applied to a handle attached to an adjustable chain. Participants were instructed to stand on the base of dynamometer with knees flexed to 30° and pull handle upwards with maximal force while extending the spine and to maintain the isometric hold for 10 seconds. During measurement of leg strength participants maintained a 110° knee flexion and simulated the action of rising from a chair while exerting maximal force on the handle of the dynamometer [28].

Statistical analysis

Statistical analysis was performed using the SPSS Version 24 software. Normality of data was tested using the Shapiro–Wilk test. As the data followed normal distribution, parametric tests were used for further analysis. Measures of central tendency and dispersion were calculated. RMS of muscle activity normalised with RMS of MVC was used for analysis. Muscle activity during single squat, sustained squat and fast repetitive squat was compared using ANOVA. BMI and IPAQ scores were used as covariates while comparing muscle strength between the three groups using ANCOVA. Correlations between variables were analysed using Spearman's correlation coefficient.

Results

Demographic characteristics of the three groups are presented in Table 1.

All three groups were matched on marginal distributions for age and gender. However, it was difficult to match the three groups on body mass due to inherent lifestyle variations in groups. Daily deep-squat exposure was nil in non-squatters, moderate in ADL-squatters (mean exposure 33 min/day) and high in occupational squatters (mean exposure 104 min/day).

Habitual physical activity was scored using the International Physical Activity Questionnaire – Short Form. Large standard deviations were observed in habitual physical activity with habitual squatters reporting higher levels of physical activity than non-squatters (Table 1).

Table 1. Demographic characteristics, habitual physical activity and daily squat exposure in non-squatters, ADL squatters and occupational squatters

Variable	Non-squatters n = 15 Mean (SD)	ADL squatters n = 14 Mean (SD)	Occupational squatters n = 11 Mean (SD)	*p-value* using ANOVA/ANCOVA
Age (years)	36.3 (3.4)	36.7 (5.2)	39.3 (5.7)	0.221
Height (cm)	157.9 (8.8)	161.1 (10.9)	155.2 (8.3)	0.117
Body mass (kg)	65.9 (11.6)	60.4 (16.6)	51.2 (10.1)	<0.001*
BMI (kg/m^2)	26.4 (3.8)	22.9 (4.4)	21.2 (4.0)	<0.001*
IPAQ score (MET min/week)	326.3 (605.4)	1048.3 (2722.0)	1943.8 (4219.8)	0.193
Daily squat exposure (min)	0	33.7 (28.6)	104.5 (96.8)	<0.001*
		Muscle strength		
Trunk dynamometry (kg)	61.5 (27.4)	63.1 (33.9)	78.2 (35.2)	0.485
Leg dynamometry (kg)	42.6 (15.8)	46.6 (19.38)	54.3 (19.35)	0.368

Note: ADL – activity of daily living
* level of significance $p < 0.05$

Table 2. Performance on 30-second deep squat test and muscle activity of seven prime movers of trunk and lower extremities during 30-second repeated deep squat and 30-second sustained squat in non-squatters, ADL squatters and occupational squatters

Variable	Non-squatters Mean (SD)	ADL squatters Mean (SD)	Occupational squatters Mean (SD)	*p-value* using ANOVA
30-sec DST reps	13.8 (3.0)	13.7 (3.1)	14.0 (5.5)	0.857
		RMS % MVC during 30-sec repeated deep squat		
Erector spinae	320.6 (240.2)	249.6 (168.2)	261.6 (178.7)	0.712
Rectus abdominis	213.6 (118.6)	175.2 (118.3)	214.1 (292.9)	0.843
Gluteus maximus	187.6 (169.4)	122.0 (86.4)	114.8 (77.4)	0.391
Gluteus medius	245.1 (474.3)	144.1 (189.2)	95.9 (34.2)	0.606
Vastus lateralis	245.9 (171.8)	232.6 (202.6)	128.9 (54.8)	0.404
Biceps femoris	337.5 (384.8)	534.9 (571.8)	115.6 (45.5)	0.160
Gastrocnemius	482.7 (452.0)	218.3 (197.0)	177.9 (100.2)	0.597
		RMS % MVC during 30-sec sustained deep squat		
Erector spinae	38.7 (19.5)	57.8 (49.8)	65.1 (45.5)	0.559
Rectus abdominis	62.3 (70.5)	83.1 (115.3)	114.3 (124.4)	0.532
Gluteus maximus	39.4 (61.0)	49.0 (46.5)	39.3 (41.1)	0.907
Gluteus medius	20.0 (19.2)	14.9 (9.8)	33.2 (44.2)	0.378
Vastus lateralis	31.6 (19.4)	63.7 (83.4)	46.8 (42.5)	0.590
Biceps femoris	36.1 (39.0)	28.6 (30.6)	30.5 (23.5)	0.900
Gastrocnemius	43.8 (55.1)	14.2 (8.6)	35.3 (45.2)	0.458

Note: ADL – activity of daily living; DST – deep squat test
Level of significance $p < 0.05$

A single deep squat elicited substantial activation of all tested prime movers of the trunk and lower extremities in all the three groups of healthy adults. The average time taken to perform a single squat was 4.5 sec, with the mean speed of 0.226 m/s. The average speed of descent was 0.209 m/s, whereas the speed of ascent was 0.247 m/s in a single squat.

During the 30-second repeated fast deep squat test, participants could perform on average 13.7 squats (SD 3.9). Mean time taken to perform one squat during fast repeated squatting was 2.3 sec, while the speed was 0.447 m/sec, which was 2 times the speed of a single squat. Therefore, it was not surprising that repeated deep squat elicited 2.5-10 times greater muscle activity compared to a 30-second sustained squat ($p < 0.05$-‑0.001). Non-squatters demonstrated muscle activity equivalent to 1.87-4.82 times MVC, ADL squatters 1.22-‑5.32 times MVC and occupational squatters presented 0.95-2.21 times MVC during repeated squats. In turn, during sustained squatting lower muscle activation

Table 3. Comparison of muscle activity during descent, sustained and ascent phases of single squat among non-squatters, ADL squatters and occupational squatters

	Non-squatters Mean (SD)	ADL squatters Mean (SD)	Occupational squatters Mean (SD)	*p-value* using ANOVA
	RMS % MVC during descent phase of squat			
Erector spinae	147.8 (202.9)	143.1 (160.3)	137.6 (99.3)	0.992
Rectus abdominis	101.0 (71.3)	64.6 (40.2)	64.3 (72.1)	0.405
Gluteus maximus	118.6 (172.2)	58.8 (43.6)	140.8 (122.7)	0.744
Gluteus medius	45.0 (43.3)	52.5 (48.9)	134.5 (260.1)	0.409
Vastus lateralis	112.3 (54.7)	64.2 (24.6)	77.9 (44.1)	0.072
Biceps femoris	287.7 (564.7)	268.2 (249.4)	322.8 (559.0)	0.968
Gastrocnemius	167.4 (101.2)	34.7 (33.1)	135.5 (88.2)	0.228
	RMS % MVC during sustained phase of squat			
Erector spinae	38.4 (23.3)	56.6 (45.4)	59.5 (22.1)	0.377
Rectus abdominis	64.4 (78.6)	55.7 (44.7)	33.2 (39.6)	0.573
Gluteus maximus	23.3 (30.4)	30.4 (29.4)	48.8 (33.9)	0.478
Gluteus medius	15.5 (15.3)	22.8 (27.4)	43.7 (84.5)	0.503
Vastus lateralis	26.9 (14.9)	22.3 (17.3)	37.0 (19.1)	0.246
Biceps femoris	99.3 (135.6)	52.7 (109.3)	22.4 (15.8)	0.390
Gastrocnemius	98.4 (99.5)	13.4 (4.4)	22.7 (21.7)	0.073
	RMS % MVC during ascent phase of squat			
Erector spinae	196.3 (202.7)	118.5 (65.3)	217.2 (175.9)	0.418
Rectus abdominis	94.3 (88.4)	81.4 (86.8)	69.4 (55.6)	0.826
Gluteus maximus	103.5 (86.9)	93.2 (73.9)	290.3 (183.9)	0.327
Gluteus medius	82.6 (125.1)	71.6 (68.5)	243.0 (196.2)	0.408
Vastus lateralis	146.1 (81.8)	87.1 (43.2)	75.3 (58.0)	0.070
Biceps femoris	345.6 (357.6)	166.3 (165.0)	210.7 (161.9)	0.265
Gastrocnemius	201.7 (178.3)	127.5 (96.3)	147.8 (50.3)	0.909

Note: ADL – activity of daily living
Level of significance $p < 0.05$

equivalent to 0.20-0.62 times MVC was observed in non-squatters, 0.14-0.83 times MVC in ADL squatters and 0.30-1.14 times MVC in occupational squatters.

The number of repetitions performed during a 30-second DST and muscle activity were not significantly different between the three groups (Table 2, Figure 1).

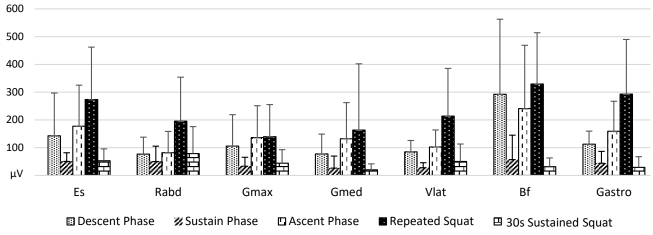

Figure 1. Average muscle activity of seven prime movers of trunk and lower extremity during descent, sustain, ascent phases of single deep squat, repeated deep squat and sustained deep squat

A moderately strong negative correlation was observed between deep-squat repetitions and age (r = –0.710, $p \leq 0.001$), whereas a moderate positive correlation was observed between deep-squat repetitions and force developed during trunk and leg dynamometry (r = 0.610, $p < 0.001$, r = 0.654, $p < 0.001$, respectively).

Secondly, we observed variations in muscle activity among the three groups of people with varying quantum of daily deep-squat exposure. Discernibly, people with varying squat exposure demonstrated varying patterns of movement during deep squat. Most non-squatters could not perform a foot-flat squat. Squat was initiated with trunk flexion, hip-knee flexion and raising heels off the ground at full depth of squat. Greater trunk flexion was observed at full squat depth. In contrast, ADL and occupational squatters could perform a foot-flat deep-squat while maintaining an erect trunk. Participants were allowed to perform a natural squat, as it was hypothesized that controlling the squat movement would influence the muscle activation pattern. Despite variations in movement pattern, no significant difference was observed in the activity of the sampled muscles, which could be due to large standard deviations in RMS (Table 3).

Additionally, force generated during trunk and leg dynamometry did not differ significantly between the groups. There was a relatively marked negative correlation between strength measures and age (r = –0.381, p = 0.01 and r = –0.405, p = 0.006 respectively) (Table 1). A very strong positive correlation was observed between trunk and leg muscle force (r = 0.810, $p < 0.001$). No influence of the habitual level of overall physical activity or BMI was observed on trunk-leg dynamometry force when the IPAQ scores and BMI were used as covariates.

Discussion

The current study explored activation of spine and lower extremity muscles during single squat, sustained and repeated deep squat using electromyography along with a comparison of muscle activity and muscle strength in people with varying squat exposure.

Although numerous muscles are recruited during deep squat, only the prime movers of the spine and lower extremities were evaluated in this study due to the technical limitation of available EMG channels. Bodyweight deep squat activated all seven selected muscles. Greater activation was observed during the ascent (81-240% MVC) and descent phases (76-292% MVC) compared to the sustaining phase of squat (27-58% MVC). Higher EMG activity during repeated squatting may be attributed to greater angular speed compared the sustained static phase of a sustained squat. Dynamic squatting demands greater muscle activation in order to maintain joint stability and a satisfactory execution technique [4, 17, 18]. Non-squatters demonstrated greater activation of the erector spinae (3.2 times MVC), vastus lateralis (2.4 times MVC), biceps femoris (3.3 times MVC), vastus lateralis (2.4 times MVC) and the gastrocnemius (4.8 times MVC), which may be attributed to the greater forward flexion of the trunk, need for greater stabilization of the knee and the plantar flexed foot during squat. Comparatively, ADL and occupational squatters required lower muscle activation during repeated squat as they were habituated to performing squat. The lower recruitment of the erector spinae (2.4-2.6 times MVC), vastus lateralis (1.2-2.3 times MVC) and the gastrocnemius (1.7 -2.1 times MVC) in ADL and occupational squatters may be a result of motor engrams formed during the habitual activity associated with a reduced synergistic muscle activity, greater stability of the knee, enhanced postural control leading to lower proximal hip and distal ankle muscle activation. Compared to dynamic squatting, lower muscle activation was observed in all the three groups during sustained squat. Sustaining the squat posture brought about contact between the posterior thigh-calf and anterior abdominal wall-thigh, which offered passive stability to the trunk and pelvis and reduced overall muscle activity required to sustain the posture.

Secondly, substantial co-activation of the erector spinae–rectus abdominis, biceps femoris–vastus lateralis and the gluteus maximus–gluteus medius was observed during deep squat. Similar findings are reported while performing partial and parallel squats to varying depth [12]. During repeated squat, the muscle activity ratio of the erector spinae : rectus abdominis pair was 1.3, whereas during sustained squat it was 0.6, indicating that the erector spinae was activated to a greater extent during dynamic squatting, whereas its activity reduced during sustained squat due to the passive anterior support. In contrast, the ratio between the vastus lateralis : biceps femoris pair was 0.7 during repeated squat and 1.5 during sustained squat, indicating that a greater activation of the hamstring muscles was required to maintain knee stability to sustain the posture. Thus, repeated squat emerges as an effective exercise bringing about activation of dynamic stabilisers of the spine, hip and knee.

Additionally, published reports indicate that muscle activity equivalent to 10-25% MVC is effective in stabilizing the spine during functional activities of daily living [5]. Observations from this study demonstrated that repeated squats elicited substantial activation of prime stabilisers of the spine, namely the erector spinae and rectus abdominis, which was 1.3-5.3 times greater than in the case of sustained squat. Fast, repetitive activity of short duration could result in post-activation potentiation and enhancement of muscle performance due to an increased excitability of α–motoneurons and recruitment of fast-twitch muscle fibres [15, 26, 29]. Thus, dynamic deep squat training at progressive speeds may be useful in strengthening programs for people with trunk and lower extremity muscle weakness.

While repetitive, dynamic squat results in greater muscle recruitment, sustaining squat would result in the passive stretch of soft tissues, thereby influencing the lower extremity joint range of motion [2]. Hence, sustained squat would provide benefits in terms of joint motion, whereas a repetitive dynamic loading stimulus may be of greater benefit in strengthening programs targeting lower extremity and spine muscles. Previous studies have established that strength training of spine and lower limb muscles is beneficial for people with degenerative disorders such as knee osteoarthritis [10], low back pain and osteoporosis [8], thus making it imperative to address muscle dysfunction and imbalance prophylactically. Specifically, weakness of knee extensor muscles is associated with increased risk of developing symptomatic and functional deterioration in people with knee OA and weakness of spine muscles in people with low back pain. Hence, bodyweight exercises such as squat that target muscle strength can be included as an integral component of rehabilitation and health promotion programs.

Furthermore, we explored differences in muscle strength among people with varying habitual squat exposure. Although muscle strength increased with daily squat exposure, the difference was not significant. This may be due to the fact that habitual squatters were required to largely sustain deep squat posture for a prolonged duration of time rather than perform repeated dynamic squats. High duration exposure to static squat probably did not provide a sufficient stimulus to bring about physiological adaptations characteristic to dynamic, repetitive high intensity training [6, 14]. On a positive note, even people who had given up adopting squat for performing ADL, could perform both repeated squats and sustained squat, although with slight alterations in movement patterns. These observations indicate that dynamic squat training can be safely initiated by both non-squatters and habitual squatters, and included into daily routine to obtain benefits such as greater mobility and muscle strength.

Certain limitations of the study cannot be overlooked. Deep squat is a large range of motion activity, involving contact between body segments resulting in movement artefacts. These limitations were addressed by accurate positioning of electrodes, visual inspection of raw and processed data for artifacts, deletion of corrupt data and outliers from analysis. However, sEMG results may be interpreted with caution for such muscles as the biceps femoris, which was prone to greater artefacts.

Conclusions

Deep squat resulted in substantial activation of spine and lower extremity muscles. Repeated squatting elicited highest activity levels, which was 2.5-10 times greater muscle activation than sustained squat. Muscle activity and strength were similar in people with varying squat exposure, suggesting that engaging in a dynamic squat activity, over and above habitual activities of daily living involving sustained squatting, is essential to obtain greater benefits in muscle strength.

Conflict of Interests

The authors declare no conflict of interest.

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