Addressing movement patterns by using the overhead squat

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INTRODUCTION

Movement screening is a concept that has been widely adopted by the strength and conditioning (S&C) community. Addressing poor movement patterns can have implications on programme design and, if done appropriately, will positively contribute to an athlete's overall physical development. The squat is one of the most utilised movement patterns in the development of lower body strength, with multiple variations (back/front/overhead) being used to target specific strength development. However, compromised form during any of these variations may lead to altered joint kinematics, thus reducing the optimal path of movement efficiency.

The overhead squat has been commonly used in well-established screening methods such as the Functional Movement Screen (FMS)[2, 4, 6, 9, 12, 16, 17] and the National Academy of Sports Medicine (NASM) screening methods.[5] Typically, this exercise is used in screening protocols in an attempt to gain a picture of movement quality that challenges mobility through key structures such as the ankle, hips and thoracic spine.[3] The FMS grades competency in this exercise through a numerical system (0–3: whereby 3 = perfect form, 2 = performed with a compensation, 1 = poor technique with major compensations and 0 = unable to perform the test due to pain).[2] The NASM method has no numerical grading system; instead it outlines specific movement dysfunctions at the major joints in the kinetic chain (see Table 1), and provides the practitioner with suggestions on how to minimise the effect of these compensations.

However, although this can be very useful information, it has been previously acknowledged that screening protocols that do not assess movement quality under load or at high velocity lack the notion of specificity to sport.[3] This has been further supported in a couple of research studies by Frost et al,[10, 11] who also suggested that the FMS may be useful when aiming to identify asymmetries in movement quality – but also that adding load and/or speed may reflect both movement capacity and risk of injury in a more accurate manner.

With this in mind, the purpose of this article is to outline how the overhead squat can be used to accomplish both of these suggestions, thus demonstrating its high level of applicability in screening protocols. It should be noted that when discussing how squat mechanics are altered under load and/or speed, the authors were able to identify only one study pertaining directly to the overhead squat: therefore, other studies addressing alternative squat variations will be used for comparison purposes.

Table 1: Suggested guidelines for movement compensations, and/or under-/over-active muscles during the overhead squat (adapted from NASM Essentials of Personal Fitness Training).

VIEW	CHECKPOINT	MOVEMENT COMPENSATION	POSSIBLE UNDER-ACTIVE MUSCLES	POSSIBLE OVER-ACTIVE MUSCLES
Anterior	Foot/Ankle complex	External rotation	Medial gastrocnemius, medial hamstrings, Popliteus gastrocnemius	Soleus, Lateral TFL, Bicep femoris (short head)
Anterior	Knee	Adduction	Gluteus maximus, Gluteus medius, VMO, Medial hamstrings	Adductor complex, TFL, Vastus lateralis
Lateral	LPHC	Excessive forward lean	Gluteus maximus, Anterior tibialis, Erector spinae	Soleus, Gastrocnemius, Hip flexor complex
		Lower back arches	Gluteus maximus, Hamstrings, Intrinsic core stabilisers	Hip flexor complex, Erector spinae, Latissimus dorsi
Lateral	Shoulder	Arms fall forward	Mid/lower traps, Rhomboids, Rotator cuff	Latissimus dorsi, Pectoralis major, Teres major

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The addition of load

To the authors' knowledge, there have only been a couple of studies that have directly looked at the kinematic or kinetic effects of load on squat movement mechanics. Frost et al[10] investigated the influence that load has on movement behaviour of 52 firefighters. Subjects performed the squat protocol under three conditions: bodyweight, with a weighted vest (weighing 18.2 kg) or 'as fast as was comfortable', which was considered as the addition of speed. For the addition of load, the aim was not to explore how heavy a weight subjects could lift, but to simply identify any alterations in movement mechanics with the addition of load.

It was reported that when load was added, there was a significant change in movement mechanics whereby both the hips ($p < 0.001$) and knees ($p < 0.025$) translated further forward when compared to the bodyweight squat, which was measured by their corresponding distance to the ankle joint.[10] However, although significant alterations in movement mechanics were noted, no actual distances of changes in distance from hip or knee to ankle were reported within the study. Furthermore, this study investigated the changes in movement behaviour for four other movement patterns (lifting a box from the floor, lunging, cable push and cable pull). Results indicated that when load was added there were 125 unwanted spinal or frontal plane movement patterns compared to 39 without the load.[10] Unfortunately, the results did not differentiate across which tests these unwanted patterns were distributed, making it impossible to know how many negative movement patterns were specific to the squat under the loaded condition.

In contrast to the results seen in Frost's research, Flanagan and Salem[7] investigated the effects varying loads had on lower extremity joint kinetics. Subjects consisted of 18 healthy adults who performed three sets of three repetitions for the back squat to 90° at 25, 50, 75 and 100% of their 3RM back squat (determined in a previous testing session). The purpose was to identify how much work and net joint moment was being carried out by the hip, knee and ankle under these four loading conditions. Results can be seen in Table 2 (on page 9).

The results in Table 2 highlight that, at all loads, subjects utilised a 'hip hinge' strategy to perform the back squat, as demonstrated by the significantly higher joint moments at the hip joint. This means they were pushing their hips backwards in order to complete the task, a movement pattern that is in fact opposite to the results seen in Frost's study. What is interesting is that the role of the hip increased as the load increased, suggesting that movement mechanics will continue to alter under varying loads. When compared to the exercise selection in Frost's study, it is evident that when load is positioned on the back of the shoulders (as per back squat technique), a hip hinge strategy is commonly adopted which falls in line with the suggested technique of this exercise.[13]

It must be remembered that these studies did not specifically use the overhead squat in their methodology when looking at alterations in movement behaviour.

However, both the squat (performed with arms stretched out in front of the body) and the back squat provide a very similar movement pattern to that of the overhead variation. The practical point to draw from Frost's study is that the addition of load actually reinforced negative movement behaviour that may not have been seen without it, suggesting that its addition can successfully challenge the movement behaviour of well-trained individuals. Similarly, the contribution from key joints in the lower body (primarily the hip) alter depending on the load being lifted during the back squat,[7] again justifying the use of load in screening protocols to identify whether movement is consistent with the original screen. This in turn may provide a rationale for using a loaded overhead squat as a progression to the commonly used bodyweight screens or versions that use a wooden/plastic dowel for this exercise. By doing so, this may highlight movement compensations that could otherwise be missed and help ensure a safe starting point for programme design.

Furthermore, although not looking at 'how movement mechanics changed', Aspe and Swinton[1] investigated muscle activity (via electromyography – EMG) during 60, 75 and 90% of 3RM overhead squat and back squat in 14 subjects. Rectus abdominis and external oblique activity was significantly higher (2-7%) during the eccentric phase of the overhead squat compared to the back squat.[1] This notion of increased anterior abdominal activation may be explained by the arm position overhead, where the latissimus dorsi (LD) muscle is put in a lengthened position. One of the LD's origins is at the iliac crest, and limited extensibility of this muscle will 'pull' on the pelvis in an anterior direction as a compensation pattern for reduced flexibility.[5] In turn, the higher activation of the anterior abdominal muscles during this version of the squat may occur as a 'counter-measure' to the LD pulling on the pelvis anteriorly, in an attempt to stabilise the hips during a dynamic movement pattern, a function which has been previously reported in the anterior abdominal muscles.[5]

Therefore, if we are to add load to the overhead squat, a realistic starting point would be to use an Olympic barbell (20 kg) to see if any of the suggested movement compensations described in Table 1 become exacerbated. A weighted vest (18.2 kg) in Frost's study[10] was enough to induce alterations in technique, thus an Olympic bar would appear to be a comparable load for progressing through the overhead squat screening process. Finally, if 60% of a 3RM overhead squat load is enough to induce significantly greater abdominal activation (2%) when compared to the back squat, then progressively adding load up to this intensity may continue to highlight trunk strength and hip stability issues in an athlete's overhead squat pattern. How quickly this load is added throughout the screening process is dependent on form and up to the discretion of the S&C coach.

The addition of speed

In the same aforementioned study by Frost et al,[10] the second variable used to identify alterations in movement behaviour was speed. Subjects were instructed to complete each repetition of the squat protocol 'as fast as was comfortable'. Results indicated that subjects adopted the opposite strategy to when squatting with load; this time hips were significantly ($p < 0.001$) pushed backwards, which also resulted in significantly less knee flexion ($p < 0.089$) when compared to the regular bodyweight squat protocol. The authors attributed this change in movement pattern to a couple of possible explanations.

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Table 2: Mean net joint moment work (WORK = J/kg) and average net joint moment (NJM = N·m/kg) for the hip, knee and ankle at 25, 50, 75 and 100% of subjects' 3RM back squat (adapted from Flanagan and Salem, 2008).

	HIP		KNEE		ANKLE	
LOAD	WORK	NJM	WORK	NJM	WORK	NJM
25%	1.31*	2.05	1.23	1.35	0.19	0.60
50%	1.82*	2.96	1.34	1.59	0.28	0.95
75%	2.51*	3.93	1.38	1.76	0.37	1.33
100%	3.33**	4.89	1.52	1.97	0.51	1.75

* indicates hip > knee > ankle ($p < 0.02$)

** indicates hip > knee and ankle ($p < 0.001$)

It was suggested that by adding the notion of speed to the test, it may have altered their attentional focus from what their body was supposed to be doing during the task to the speed of execution.[10] This would have resulted in a shift from an internal focus (what their body needs to do) to an external focus (speed of movement), causing the subjects to forget or ignore the most effective method to move. This notion of shifting one's attentional focus has been shown to alter movement behaviour.[18]

A second explanation proposed that the firefighters may have found it easier to squat quickly by adopting a more hip dominant strategy. The authors suggested that when the hips are moved backwards, less effort is required by the knee extensors, which will reduce the stress on the knee joint and in turn may reduce the potential for injury.[10]

Once again, results must be interpreted with caution as these two explanations were merely suggestions. The concept of internal versus external focus – while plausible – was not investigated during this study, and as such cannot be substantiated. In addition, the second suggestion of using the hips more at higher speeds when squatting may follow a logical line of thinking in terms of reducing the effort on the knee extensors, but similarly the only way one could have supported this claim would have been to measure muscle activation under all conditions – something which again was not the focus of the study.

Practical application

Firstly, although most of the literature discussed in this article does not directly relate to the overhead squat, the principles of adding load and/or speed can still be applied when screening an athlete's movement with this exercise. The overhead squat's inclusion in screening protocols to date is commonplace, most notably because of its capacity to challenge athletes' mobility in key joints such as the ankle, hips and thoracic spine.[3] The rationale for using the overhead version of the squat exercise when screening movement is supported by the results from Aspe and Swinton,[1] where the anterior trunk muscles may be challenged to a greater degree than the back squat variation; thus screening movement without the arms overhead may result in coaches missing some vital information regarding trunk stability.

Secondly, Frost et al[10] also advocated some practical tips regarding modifications in movement behaviour. When interpreting the results of the group as a whole, it is feasible to identify trends in movement patterns when responding to different variables such as load or speed. However, it is likely that alterations in movement were brought about for a variety of reasons at an individual level. Such reasons may consist of understanding of the task, attentional focus and previous experience.[8, 15, 18] With this in mind, simply viewing whether an athlete demonstrates compensation when the conditions of the assessment are changed may help to identify any detrimental motor patterning issues. Furthermore, the addition of load and/or speed provides a progression from the bodyweight screens most commonly used today, which again may highlight problems that could have otherwise been missed.

Finally, in a previous article by Bishop et al,[3] it was suggested how high-velocity assessments can enhance the screening process and three possible assessments were suggested to have varying amounts of neuromuscular control, thus offering a continuum of progression when screening an athlete's movement. The same principle can be applied here. Knowing that strength is a necessary pre-requisite for power and speed,[14] it seems prudent to suggest that the addition of load (starting at 20 kg) could be the first progression when using the overhead squat for screening purposes. Once this has been mastered, shifting the focus to performing overhead squats at speed (still with load if technique has been perfected) could be the second progression. The addition of these two variables may inform the S&C coach whether compensations have been truly rectified or if they simply 'do not present themselves at slow speeds', thus providing a fuller picture from the screening process as a whole.

Conclusion

It is clear to see from the limited evidence in this area that the addition of load/speed does alter movement mechanics, but further research is warranted to draw any real conclusions on this topic. The addition of load will likely alter where the athlete's centre of mass is positioned, thus a change in movement mechanics is almost inevitable. Increasing the speed of the overhead squat will most likely alter the line of movement also, although the response of the athlete may be dependent on their experience at performing this exercise in this manner. Either way, adding load and then speed could be considered viable 'next steps' when using the overhead squat in an attempt to complete the screening picture for this particular task.

Finally, should these suggestions be accepted by practitioners, a logical next step would be to identify whether those who exhibit optimal movement mechanics under load/speed during the overhead squat also screen better across any additional assessments deemed relevant for that particular athlete, thus highlighting its importance as a predictor for enhanced movement mechanics.

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