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A narrative review

Bachelor's thesis in Human Movement Science
Supervisor: Karen Emilia Ekman
May 2023

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Abstract:

Background: Movement variability has gained more attention in recent years, while earlier beliefs were that a more rigid technical model resulted in less injuries and a successful task goal. Recent research suggests otherwise. This narrative review investigated the effect of an increased task demand in the barbell back squat. Our goal was to evaluate if there was an increase in variability for kinematics in the knee, hip and torso when lifting heavier loads or when fatigued from multiple repetitions. **Methods:** We conducted a systematic search in PubMed which resulted in 41 articles, where 8 of these studies were included in the results. **Results:** Our studies show that an increase in task demand will result in more variability, where the execution variability increased in the high bar back squat and the low bar back squat had a decrease or a slight increase. **Conclusion:** Our findings are inconclusive but show an increase in execution variability in the barbell back squat with a higher task demand. Because of a limited number of studies in this review we cannot draw any conclusion. But these findings reflect that there is more need for studies investigating variability in BBS.

Abstrakt:

Hensikt: Variabilitet i bevegelse har i de siste årene fått økt oppmerksomhet, hvor man før trodde at strengere og mer identisk teknikk resulterte i færre skader og et vellykket utfall. Nyere studier vil gå vekk fra denne tilnærmingen. Hensikten med denne artikkelen var å undersøke effekten av en økt vanskelighetsgrad i knebøy. Vi ville evaluere om det var en økning i variabilitet i kinematikken av kne, hofte og overkropp under høyere vekt eller ved en utmattelse etter flere repetisjoner. **Metode:** Vi gjennomførte et systematisk søk i Pubmed som resulterte i 41 artikler, hvor 8 av disse ble inkludert i resultatene. **Resultat:** Vår undersøkelse indikerte at en økning i oppgavens vanskelighet resulterer i mer variabilitet, hvor variabiliteten i utførelsen øker ved en høy stangplassering på knebøy og en nedgang eller veldig liten økning i variabilitet ved en lav stangplassering i knebøy. **Konklusjon:** Funnene våre er inkonklusive, men det indikerer en utførelsesvariabilitet i knebøy ved økning i vanskelighetsgrad. Den begrensede andelen studier i denne artikkelen gjør at vi ikke kan komme til en konklusjon. Det reflekterer behovet for mer forskning som ser på variabilitet i knebøy

Key words: Barbell back squat, movement variability, High bar back squat, low bar back squat

Introduction:

For many years coaches have instructed their athletes to keep the same movement pattern even with an increase in task demand (e.g., heavier weights in weightlifting exercises, same golf swing) with minimal variability in the movement. Logically that would result in a more rigid technical model and a higher probability to successfully reach the goal of the task. An example of this could be throwing a basketball with the same technique, speed and movements pattern of the arm and shoulders, enchanting the movement pattern so every attempt results in the same successful outcome. It has also been taught to decrease the risk for injuries. e.g., not rounding your back during a deadlift. In later years movement variability (MV) has become more accepted as more knowledge on how the body orients itself to solve a task (Preatoni et al., 2012).

MV can be defined as the normal variation that occurs in motor performance when doing multiple repetitions of a task (Stergiou et al 2004 cited in Cowin et al 2022). It also appears that MV is unavoidable in trial to trial movement (Nordin & Dufek, 2017; Preatoni et al., 2012). There is also evidence that variability within the chosen strategy still results in the same successful task goal (Preatoni et al., 2012). So clearly some types of MV can be accepted in sport specific tasks, but the origin to the variability and the appropriate amount of variability need explanation.

We are going to use the dynamic systems theory/approach (DSA) to explain some of the aspects that cause MV and how our body orientates itself to solve a task. In DSA, movement is a result from the interaction between environmental, individual and task constraints. The body can choose movement strategies within all of these constraints, giving the body a lot of degrees of freedom (DOF) (Cowin et al., 2022; Sigmundsson et al., 2017). Bernstein (1967) produced a theory of how the body counteracts this DOF problem in motor learning. He proposed three distinct stages of learning; The first is freezing DOF so that the remaining DOF are easier to control. The next stage releases more degrees of freedom allowing more flexible and effective movements. The final stage allows utilization or exploitation of external forces to make the movement economical and efficient. An example of this is discussed in Nordin & Dufek (2019). They measured less change in the kinematics of the ankle, knees and hips when dropping from a given height. While the environmental demand increases (increased the fall height) the body (individual constraints) freezes DOF to prevent an unwanted or too much variability to prevent acute injuries. The task stays the same, but there is variability of how the task is solved. Together DSA and Bernstein's theory forms a structure for the body to self-organize, based on the individual's current level, the environment and the task at hand (Sigmundsson et al., 2017).

Moreover, it is important to understand that the interaction between segments or joints can influence the motion of other segments and joints. This is usually referred to as coupling, and it is important for coordinative variability functional roles (Hamill et al., 2012). A looser coupling between selected segments seems to be the norm for healthy individuals with less injuries, and tighter couplings lead to a higher prevalence of injuries. (Hamill et al., 1999; Nordin & Dufek, 2019). There's evidence that individuals after an injury have less coordination variability and have a reduction of coordinative patterns of segments (Hamill et al., 2012; Seay et al., 2011). Lack of variability results in more rigid movement patterns causing more tissue breakdown (Bates, 1996). This does not necessarily mean that biomechanical research always reflects the complexity of injuries, but it might show an increased risk for overuse injuries. There is also an increased risk for more traumatic injuries when the movement has too much uncontrolled or unwanted variability. Uncontrolled variability is when the body unintentionally moves in an extra wide or large movement proximity, causing stress on tissue that isn't used to that type of load (Hamill et al., 2012). The appropriate amount of variability is speculated to be a "goldilocks" zone, where too much variability increases the risk for a more traumatic injury and less increases the risk for an overuse injury. Coordinative variability can be looked at as the result of how the individual restraints react during the solving of the task and is probably affected by experience and level of fitness - which is something this review investigates.

When measuring MV earlier, biomechanical research has traditionally looked at variability as noise, and typically eliminated the results from the data as errors (Hamill et al., 2012). Traditional linear measurement e.g. averages represented with standard deviation (SD) might give a window to describe variability around a central point (Stergiou & Decker, 2011). However this relies on the assumption that the data are normally distributed that might inflate the variability assessment, making it harder to detect the impact of variability (Preatoni et al., 2012). A proposed form of measuring variability is a nonlinear approach, measuring the flexibility and ability to choose different strategies. Specifically, being able to measure significant differences in coordinative variability and how the body solves a task. Unfortunately this way of measuring is relatively new and a lot of kinematic studies don't represent these types of data (Preatoni et al., 2012; Stergiou & Decker, 2011).

To better evaluate distinct types of variability Cowin et al (2022) produced a proposed framework built upon multiple earlier established frameworks, for systematically measuring

MV. They split variability into three categories. The first is *Strategic variability* (SV) and is the selected strategy for a task. This strategy can either be voluntary or involuntary and are often based on the environment and individual constraints related to the task goal. The second is *Execution variability* (EV) and describes the intentional and unintentional adjustments of the body during repetitions or within the same chosen strategy. This makes it possible to quantify variability within a single strategy. Lastly *Outcome variability* (OV) that describes the result of the movement. For this narrative review where the purpose is to systematically measure MV in a barbell back squat (BBS). We use the strategic variable to divide the BBS into two distinct categories: A high bar back squat (HBBS) and a low bar back squat (LBBS). The main difference is a greater torso forward lean in LBBS (Glassbrook et al., 2017), increasing forces on the hip joint compared to the knee joint (E. Kristiansen et al., 2021; Wretenberg et al., 1996), while the HBBS is characterized by a greater knee flexion, and a deeper bottom position and a significant difference between knee and hip peak angles (Glassbrook et al., 2019). Therefore, measuring EV in torso, knee- and hip joint angle in each strategy could give us a more exact measurement of variability when looking at the SD around the average. If we were to compare variability without categorizing the different strategies there would have been more EV, when looking at knee, hip, and torso kinematics. By using this type of framework, the SD around an average might give a better understanding of EV.

To the authors knowledge, no other reviews have looked at variability in complex sports related coordinative movements with an increased or a high task demand (Preatoni et al., 2012). This narrative review followed a structural literature search for kinematic studies in the exercise BBS. We investigated if there was a decrease in EV as seen in Nordin & Dufek (2019), by looking at knees, hips or torso when increasing the external load or the task demand (e.g., fatigue after multiple repetitions). It is important for trainers and coaches to get a better understanding of how the body organizes itself under heavy loads to solve the task goal both to increase performance and understanding when there is a higher injury risk.

Method/research methods:

For this narrative review we conducted a systematic search in PubMed because it suits our aim for this narrative search with reliable sources to give us insight about the topic. Our search was done on 16. March 2023, and resulted in 41 articles, keywords that were used in the search are listed below. The search is narrowed down to only incorporate a difference in movement strategies in a barbell back squat as defined above, to give a more representative measurement of EV.

"*Biomechanics* OR *kinematics* OR *coordination* OR *motor pattern*" AND "*Barbell back squat* OR *Backsquat* OR *Back squat* OR *squat*" AND "*Barbell placement* OR *Stance Width* OR *Narrow stance* OR *Wide stance* OR *high bar barbell back squat* OR *High bar squat* OR *Low bar barbell back squat* OR *low bar squat*"

All the results were screened for kinematic or measurement of biomechanical aspects, movement strategies (e.g., barbell placement) in a barbell back squat. Studies were excluded during screening if they did not include kinematic or a barbell back squat with external load or if they only looked at EMG (muscle activity) or if they did not describe the strategy that was used. After title screening 16 studies were chosen for abstract reading. 12 studies were included for full text screening. Studies were excluded if they did not report any linear changes in kinematic or kinetic when increasing weight or task demand. After full text screening 8 was included in the results. The process is illustrated *in figure 1*.

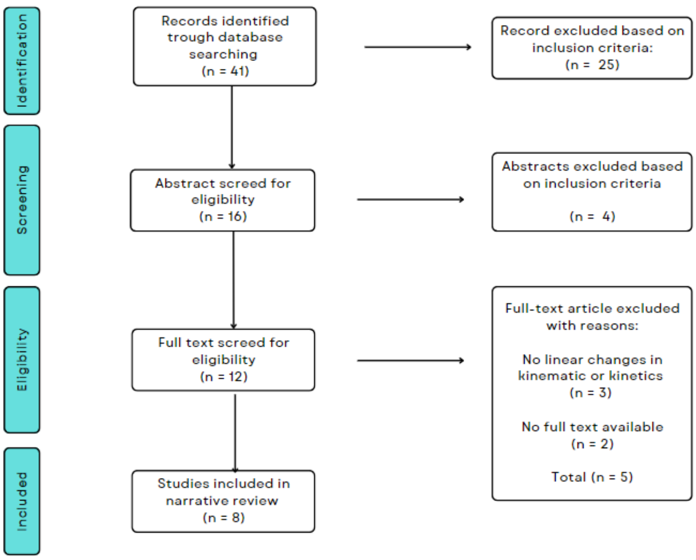

Figure 1: Illustration of screening process.

Findings:

Most of the studies included knee and hip kinetics during the lift. But there is a difference in how they represented it. Glassbrook et al (2019) defined it as actual and raw joint angles. The actual joint angle of the knee joint is measured between the greater trochanter on the hip and the lateral malleolus on the heel. The raw angle is measured differently. Usually by measuring the knee joint angle based on the position of the femur compared to the tibia and imagining a straight line going through the joint, where the distance to the line is the angle. The lower numbers are actual angles (Glassbrook et al., 2019; Lahti et al., 2019; van den Tillaar et al., 2020) and higher numbers are raw angles (E. Kristiansen et al., 2021; Larsen et al., 2021) both measure the same task, but give out different results which can be seen in table 1.

Peak hip joint and change in SD:

The HBBS had a steeper hip flexion than the LBBS in some of the studies (Glassbrook et al., 2019; Swinton et al., 2012; van den Tillaar et al., 2020), Larsen et al (2021) had very small differences in peak joint angles for all conditions (<1 degree difference) and Kristiansen et al (2021) had a lower peak flexion in the HBBS condition than the LBBS condition. There was also one study restricting the depth in the BBS for the participants (Lahti et al., 2019) resulting in less flexion for the hips more similar to the LBBS. When increasing the task demand the HBBS showed a greater increase in SD, while the LBBS had a decrease in SD (van den Tillaar et al., 2020) and an increase in Glassbrook et al (2019). For Lahti et al (2019) the wide stance had a greater increase in SD than the narrow stance. Some of the studies that had the highest intensity also reported the highest amount of increase and decrease in SD (Glassbrook et al., 2019; E. Kristiansen et al., 2021), but there was a rather small difference.

Peak knee joint and change in SD:

The HBBS showed more peak flexion than the LBBS in multiple studies (Glassbrook et al., 2019; E. Kristiansen et al., 2021; Larsen et al., 2021; Swinton et al., 2012; van den Tillaar et al., 2020), with a couple studies having quite similar peak flexion depending on the condition e.g. Larsen et al (2021) HBBS wide stance. Lahti et al (2019) reported more peak flexion in the wide feet condition compared to the narrow feet condition. With few of the studies reporting changes, only two reported their data on changes in kinematics. There were more changes in SD for LBBS conditions in Glassbrook et al (2019) than the narrow stance in Lahti et al (2019) but not for the wide feet stance. Swinton et al (2012) presented the changes in joint kinematics as an average because the external resistance (30, 50 and 70% of 1RM) was found to have minimal effect for the different BBS techniques. Sinclair et al (2022) reported their kinematic data as the mean value of foot placement angle of 0º, 21º and 42º, where all trials had the same task demand of 70% of 1RM.

Thoracic angle change and change in SD:

When looking at the change of thoracic angle only two studies reported their findings (E. Kristiansen et al., 2021; Larsen et al., 2021), while one study reported curvature of the spine/torso (Sayers et al., 2020). Two of the studies reported changes on different timestamps within the lift. In Larsen et al (2021) there were quite minor changes in SD from the lowest part of the lift V_0 and D_{max}, which is the part of the lift where the deceleration of the barbell is at its highest, also known as the beginning of the sticking region. They reported a slight increase for the LBBS and a very small decrease in the HBBS. Kristiansen et al (2021) used different timestamps, where V_0 is the same as in Larsen et al (2021) but V_{max1} is the highest velocity of the barbell pre-sticking region. They showed a larger change in SD for the HBBS condition, and no change in the LBBS condition. Sayers et al (2020) reported no change in SD for both of their conditions, but there was an increase in average thoracic curvature for both conditions, and a bigger change for the recreationally trained participants

Table 1: Overview of studies and kinematics

Studies	Participants	Conditions	Load (% of 1RM) OR Increased demand	Peak angle knee (°)	Peak angle hip (°)	Changes in thoracal angle (°) /curve (c)	Changes in SD
Lahti et al 2019	R (n = 14)	Narrow feet- placement	70	105,8±2,8	107,1±5,6		↑0,3 (knee)
			85	104,4±3,1	105,7±6,1		↑0,5 (hip)
		Wide feet- placement	70	96,1±3,9	109,1±4,9		↓0,1 (knee)
			85	95,5±3,8	107,7±6,2		↑1,3 (hip)
Glassbrook et al 2019	P (n = 12)	HBBS	74-84	54±7	69±7		0,0 (knee)
			100	56±7	71±9		↑2,0 (hip)
		LBBS	74-84	62±11	59±9		↑1,0 (knee)
			100	63±12	59±10		↑1,0 (hip)
Swinton et al 2012	R (n=12)	HBNS	N/A	121,1±3,4*	104,3±4,9*	33,5±4,6	N/A
		LBWS		112,1±4,3*	112,6±5,8*	33,1±4,5	
Sinclair et al 2022	R (n=20)	HBBS	70	113,4±10,9	81,8±20,6	32,5±6,5	N/A
Sayers et al 2020	N (n=10)	HBBS 4,5 ° heel elevation	25% of BW			9 ± 3 (c)	
			50% of BW			10 ± 3 (c)	0,0 (torso)
	R (n=10)	HBBS 4,5 ° heel elevation	25% of BW			9 ± 3 (c)	
			50% of BW			11 ± 3 (c)	0,0 (torso)
Van den Tillar et al 2020	R (n= 12)	HBBS (n=6)	1 r		76±12		
			6 r	79±12,1*	67±13,5*		↑1,5 (hip)
		LBBS (n=6)	1 r		80±15,7		
			6 r	71±15,7*	71±10,8*		↓5,7 (hip)
Kristiansen et al 2021	R (n=14)		3RM				
		HBBS	(v_0)	123±10	110±5	48±2 (°) *	
			(v_{max1})			50±5 (°) *	↑3,0 (torso)
		LBBS	(v_0)	120±10	115±10	58±2 (°) *	
			(v_{max1})			60±2 (°) *	0,0 (torso)
Larsen et al 2021	R (n=18)		3RM				
		HBNS	(v_0)	126,4±4,7	111,0±7,2	46,7±2,9 (°)	
			(d_{max1})			53,2±2,8 (°)	↓0,1 (torso)
		HBWS	(v_0)	119,3±6,4	110,4±4,5	46,0±3,4 (°)	
			(d_{max1})			52,3±3,1 (°)	↓0,3 (torso)
		LBNS	(v_0)	122,7±5,0	110,6+6,6	56,7±2,5 (°)	
			(d_{max1})			63,5±3,2 (°)	↑0,7(torso)
		LBWS	(v_0)	120,3±5,8	111,9±4,8	53,0±4,4 (°)	
			(d_{max1})			60,7±4,8 (°)	↑0,4 (torso)

P: Professional = Active competitors at national or international level, R: recreational = 1+ years of experience with training, N: novice = regular trainers, r = repetition, RM = Repetition max, BW = Body weight V_0 = lowest vertical height, d_{max1} = sticking region, HBBS = Highbarbacksquat, LBBS = Lowbarbacksquat, HBNS = High bar narrow stance LBNS = low bar narrow stance, HBWS = High bar wide stance, LBWS = Low bar wide stance. *Significant difference between conditions P<0,5

Discussion:

The main purpose of this narrative review was to investigate if there was a decrease in execution variability when increasing the weight or demand (fatigue). Our findings are inconclusive but show that there is an increased SD in the HBBS, while the LBBS had a decrease in SD or a very small increase. Lahti et al (2019) only measured narrow or wide feet stance, showing a slight increase in SD for the narrow, and a small but increased SD in the wide stance. In addition, the studies that measured movement strategies during the lift found a low increase in SD in Larsen et al (2021) and no increase in Kristiansen et al (2021) for the LBBS conditions. While Kristiansen et al (2021) showed a greater increase for the HBBS, Larsen et al (2021) saw a very small increase of SD. Our results suggest that the LBBS could be a more rigid technical model than the HBBS, and easier for the body to freeze or to control the DOF during heavier loads. Both have some type of execution variability either by retaining or releasing DOF when increasing the task demand. For the torso, only one study showed any impactful variability when increasing task demand in the HBBS condition (E. Kristiansen et al., 2021). But with a small amount of the studies presenting the data we need to evaluate variability; we cannot conclude that our results show what we are looking for.

When comparing professional and recreationally trained participants, there does not seem to be a major difference between the two. We only had one study with professional athletes and most of the other used recreationally trained participants. The professionals in Glassbrook et al (2019) showed approximately the same SD for the hips and a steeper average joint angle for the first datapoint, compared to both of Lahti et al (2019) data points. The difference in peak joint angle could be because of their different methods, where Glassbrook et al (2019) followed the competition rules for International powerlifting federation (IPF-Rulebook). In addition, the professional weightlifters that did the HBBS always goes to a greater depth beneath what is referred to as the parallel, which in competition is a valid lift. Lahti et al (2019) stopped their participants at the depth regardless of the condition used. Which is how different method could explain the differences in peak joint angle in both hip and knee. While van den Tillar et al (2020) followed the same method as Glassbrook et al (2019), they reported a less steep angle on average in both conditions in the hip joint in their last repetition. They also had a bigger change in both average joint angle and SD compared to the professional athletes. While Larsen et al (2021), Swinton et al (2012) and Kristiansen et al (2021) used what Glassbrook et al (2019) defined as raw angles and are difficult to directly convert to actual angles for comparison purposes. Sinclair et al (2022) stays an anomaly, because the peak joint angle in the knee looks like raw angle, while the hip looks more like actual joint angles. Our interpretation is that their results don't make a lot of sense. A steep knee angle should result in a more upright thoracic angle mimicking the HBBS, which is similar to the method they used. But at the same time, they should have had a steeper hip joint angle coherent with Larsen et al (2021) and Kristiansen et al (2021) that had the same average peak knee flexion and similar peak hip flexion. The explanation could lie in the wide SD in their results, 20 degrees is a substantial difference when it comes to range of motion in a joint. This also makes us speculate on how controlled the study was, as there should have been standardized depth in the BBS for better quality in the study. Swington et al (2012) showed similar average peak joint angles as Larsen et al (2021) and Kristiansen et al (2021), with some differences especially in the hip joint for both conditions. But there are some limitations from that study, where they represented the average joint angle and SD from 30 - 70% of 1RM in the same results, making the results useless to measure variability. With a small number of studies to compare, only the results from van den Tillar et al (2020) and Glassbrook et al (2019) can give us an indication that recreationally trained athletes have more variability when the task demand is increased. Professionally trained athletes have less variability even when the task reaches maximal intensity.

It does not look like intensity affects professional athletes the same way it affects recreationally trained participants. This could be because of the testing methods used in the different studies. Glassbrook et al (2019) had a different approach where they assessed how much absolute weight the participants could lift 1RM. While van den Tillar et al (2020), Larsen et al (2021) and Kristiansen et al (2021) assessed, how many repetition the participants were able to do at the participants 3 or 6 repetition max. Both are max effort tests of the BBS that should max out a lot of the individual constraints, but according to our speculation this could result in different fatigue mechanisms resulting in different movement strategies. The fatigue from multiple repetitions could cause different movement strategies by maxing out the capacity of e.g. quadriceps musculature in the form of calcium related fatigue, limiting the capacity for motor unit recruitment and contraction (Balog, 2010; Brownstein et al., 2021). While in the 1RM method there could be less accumulated fatigue, that allows for better recruitment and coordination of the segments and "fresher" legs. As discussed in the introduction, movement of one segment results in changes of the other segments, by limiting or maxing out the contribution from one segment, the movement must change for a successful lift. This might be shown by the change in the thoracic angle change during the HBBS in Kristiansen et al (2021), or as described by van den Tillar et al (2020) that there was an observable change in movement strategies for the HBBS on the last repetition. This could have been better illustrated if we collected a different part of the lift in Larsen et al (2021), we speculate that a later part of the sticking region would show more movement strategies and a higher SD. That is because it could be a more demanding part of the lift, with a higher need for movement strategies than in the beginning of the sticking region. Making method within the studies and our data collection a limitation for explaining the variability based on intensity. In addition, with only one study on professional and the others on recreational, we cannot say for sure that the level of fitness or skill results in more or less variability.

Limitations and future direction:

In general, our review consisted of few studies around the topic, and with only some of them reporting what we wanted to investigate. We chose to only search in one search engine because of the study design that was used, and our goal was not to cover the entire literature for BBS in this review. Glassbrook et al (2019) did a larger systematic search on more platforms but found few studies that differentiated between LBBS and HBBS which we prioritized highly because we wanted to look at the EV between the two strategies. Based on our knowledge, it is only in recent years that BBS research has focused on separating and standardizing different techniques that have been seen in either competition or in practice at gyms for many years. In addition, to our knowledge only one study has used a non-linear approach to measure variability in the BBS (M. Kristiansen et al., 2019), unfortunately this study wasn’t part of our search and the reason for that was probably because it didn’t differentiate between a HBBS or a LBBS.

Initially the number of articles we ended up with is quite few, we only had 41 articles from our search. This could mean that potentially good studies were excluded without us knowing. By using more search engines, we speculate that we could have gotten more reliable studies in our review. Our pilot searches in SPORTdiscus with other platforms, we ended up with a lot of studies that did not incorporate or even looked at the BBS. In addition, a lot of the good studies on the BBS from Glassbrook et al (2017) was not a part of any of the results we got from the search. When we searched in PubMed our first screening indicated that the studies presented what we wanted to investigate. After full text screening and looking at their results, we found out that the statement from Hamil et al (2012) was exact, that a lot of the biomechanical research does not represent the values we need to look at variability.

Even though we tried to split into SV and EV other confounding mechanisms could have affected the variability measurement. One we speculate in, could be the anthropometry in the participants. We do not know if the studies that are included calculated the differences between the participants in limb lengths and their initial technique. A person with longer femur might and less dorsi flexion in their ankle, usually ends up having less knee flexion than a person with shorter femur and more dorsiflexion. These differences between participants if not accounted for could inflate the SD in their results, and by that be misinterpreted as variability in this review.

Moreover, the results from Kristiansen et al (2021) and Larsen et al (2021) are an average from 3 repetitions which could inflate the EV, because as discussed in the introduction that MV is unavoidable in trial to trial movements and the variability could be at normal result of motoric function and not from increased demand. Van den Tillar et al (2020) published data of each repetition making it easier to spot variability from one repetition to the next and might be better for measuring EV. Future research around averages should adhere to the same methods when publishing the results. This is to get a better insight of variability in the BBS, and a wider usage of the kinematic measurement in other areas of sport science.

In addition, this narrative review only focused on the sagittal plane and did not consider that this is a movement that happens in all three movement axes. The majority of the BBS moves through the sagittal plane, but it could be beneficial to incorporate the EV in the frontal plane. This would have given a greater depth and insight for movement strategies like knee adduction and abduction, which could directly have affected the changes in knee and hips joint angles and describes movement strategies in greater depth. For example, the valgus of the knees or the curvature of the back to decrease the moment arm for the hips extensors to the central line from the barbell. These changes were included in both Larsen et al (2021) and Kristiansen et al (2021) but was out of the scope for this review. Future research should incorporate variability in all different planes, to better understand how the body adapts when different segments of the body max out and causes movement strategies in the BBS.

In conclusion this narrative review looked at variability in the BBS. Our findings indicate that an increase in task demand will result in more variability in how the individual solves the task either by changing the knee, hip or torso or all angles during the lift. Variability in the BBS has not been thoroughly researched before and needs more attention in future research. Because of the small number of studies and participants, quality and what the studies reported, we cannot draw any conclusion from our findings.

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