Jump Squats
How Much Load?

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Introduction

The development of lower body power is one of the key developmental areas for many athletes as it is involved in many sporting movements and actions. Jump squats have increasingly found their way into the training programmes of many athletes and with good justification as it is a valid method for maximising power levels of the lower body.

Load

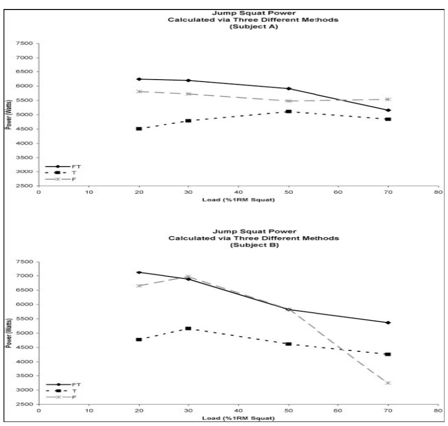
Research has advocated the use of certain percentages of 1repetitions maximum (RM) of the squat to achieve the required training stimulus to develop the required levels of power. This is the first of many problems as current research is unsure of the required percentage load of 1RM Studies by Baker, Nance and Moore (1) suggest that maximal power is best developed at 55-59% of 1RM. McBride, Triplett-McBride, Davie and Newton (2) concluded that the use of 30% of 1RM was best suited for the development of power, specifically in relation to velocity movement capabilities. Sleivert, Esliger, Bouroque (3) stated that maximal power was best developed through a range of 50-80% 1RM. Stone, O'Bryant, McCoy, Goglianese, Lehmkuhl, and Schilling (4) stated that maximal power was best developed with only 10% 1RM. How do we decipher the above to be able to decide which is the appropriate resistance level for the development of power.

Dugan, Doyle, Humphries, Hasson and Newton (5) may help to provide us with the reasons for the discrepancies between the analysis protocols and data collection methods of the studies. They state that "*there are six topics relevant to measurement and reporting of maximum power and optimal load are addressed: (a) data collection equipment, (b) inclusion or exclusion of body weight force in calculations of power, (c) free weight versus Smith machine jump squats, (d) reporting of average versus peak power, (e) reporting of load intensity, and (f) instructions given to athletes/participants.*"

Data Collection

The main experimental setups for data collection are 1. The use of displacement. 2. vertical ground reaction forces. 3. Both displacement and ground reaction forces. 4. Accelerometer.

Duggan et al, (5) state that *"Comparison of Techniques. Each of these techniques is based on valid but different mathematical premises. However, the displacement-only, VGRF-only, and accelerometer techniques are at a disadvantage because of the limited amount of data collected in each, only displacement or VGRF data. In each case, the data are manipulated, differentiated, or integrated, and this process amplifies any noise in the raw signal (for detailed discussion, see Wood [17] and Winter [16]). The increased data manipulation leads to a greater risk of accumulating error in the results and reduces the validity and reliability of the calculated power output. In addition to the disadvantage of excessive data manipulation, the VGRF-only technique requires at least 1 point within the data where velocity is zero. This is necessary to use the impulse-momentum approach, which is very sensitive to this condition. The use of accelerometry also has the disadvantage that the signal must be integrated to derive velocity data, and this can be error prone, but the greatest problems relate to orientation of the transducer and their susceptibility to damage. First, the axis of the accelerometer must remain aligned with the plane of movement, or the acceleration will not be accurately measured. Second, because of their construction and the fact that in measuring accelerations during jump squat, the magnitudes are relatively low (i.e., ,5 g), the appropriate accelerometers are rather delicate and easily damaged by any shock such as would occur if they were dropped or impacted in any way. In light of these facts, the most appropriate method of data collection is to utilize a force platform to collect VGRF and a linear transducer to accurately measure displacement (or other position-measuring device) when measuring power to determine the optimal load."*



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At each load, peak power output was calculated by each of the 3 methods, and the results are displayed in Figure 1. Clearly, quite different results are produced depending on the data set used. Note that the optimal load ranges from 20 to 50% of squat 1RM.

Clearly it may be some time before scientists can develop a truly accurate method for measuring the power output obtained from the squat jump.

Body Weight

Body weight has been included or omitted in some of the studies and this only helps to muddy the waters even further. I am in agreement with Dugan et al, (5) that the inclusion of bodyweight must be included within the equation as the total resulting power generated by the leg extensors is determined by the total load, body mass and load of the bar.

The significance of neglecting body mass is highlighted by Dugan when they state that "*By excluding body mass, a proportionately larger error is inherent at lighter loads (e.g., 20–40%) compared to heavier loads (e.g., 70–80%). This error reverses the load-power relationship. In other words, when the body mass is excluded from light loads, a greater proportion of the load is now neglected, and the decreased load will result in a lower power value. On the other hand, at relatively high loads, the exclusion of body mass is a smaller relative reduction in the load; therefore, power at the higher loads* *is less affected by the exclusion of body weight in the calculations."*

Stone et al, (3) evaluated the effect of 1 RM strength of the squat and its effect upon power output for both counter-movement and static squat jumps. The study concluded that "*The highest power outputs for both jump conditions occurred at 10% of the 1RM and decreased as the relative intensity increased. Comparisons of weak and strong subjects indicate that as maximum strength increases the percentage of 1RM at which peak power occurs also increases (40 vs. 10% of 1RM). From a practical aspect, to improve jumping power output, these results suggest that improving maximum strength should be a primary component of training programs and that strength training should shift from lighter (10% 1RM) to heavier (40% 1RM) loads."*

Boyle (6) uses the following calculations to determine total load for jump squats and it is heavily influenced by body mass, and 1RM: 1RM Squat + Body Weight (BW) = Total system Weight x .4 = Total load. Boyle suggests 40% of Total System Weight and this may equate to a good starting level that can be tailored to suit the strength of the athlete. Within the DVD Boyle uses the example of two athletes who both have the same 1RM but have different bodyweights and this highlights the importance of the inclusion of bodyweight as the heavier athlete is unable to handle the suggested total load that the conventional straight percentage of 1RM would suggest. Indeed the heavier athlete produces an negative score with Boyle's system but may be deemed safe to start this athlete with only bodyweight squat jumps. If the negative score was lower than the above it would probably be wise to increase the athletes squat strength before starting squat jump training.

1 Repetition Maximum	**Bodyweight**	**Total System Weight**	**40% TSW**
400lbs	200lbs	600lbs	240
400lbs	300lbs	700lbs	280

When we enter the relevant data based upon the results and suggestions of Dugan et al, and Stone et al, we see that stone is closer to the suggestions of Boyle with the 300lb athlete and suggests a load of + 40lbs and Dugan estimates an external load of 120lbs.

	1RM	**Bodyweight**	**Total System Weight**	**Recommended Weight**
Dugan (.4 BW)		200lbs		80lbs
Boyle (.4 TSW)	400lbs	200lbs	600lbs	40lbs
Stone (.1 1RM)	400lbs	200lbs		40lbs

	1 RM	**Bodyweight**	**Total System Weight**	**Recommended Weight**
Dugan (.4 BW)		300lbs		120lbs
Boyle (.4 TSW)	400lbs	300lbs	700lbs	-20lbs
Stone (.1 1RM)	400lbs	300lbs		40lbs

Free weights versus Smith machine

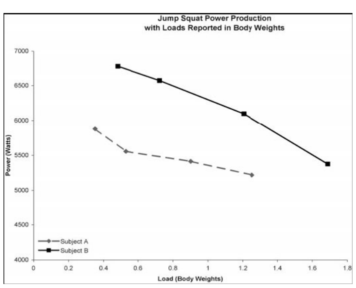
The use of smith machine for scientific purposes of providing relevant information for coach's in my mind is flawed as it does not reproduce the natural biomechanics that athlete's would use whilst jumping in activities or during squat jump training. For this reason alone I would find that the use of smith machine squat jumps to be invalid and should be discarded. Free weights on the other hand allow the body to move naturally and will allow for the necessary 3d movements that will happen whilst executing a vertical jump.

Reporting Average versus Peak power

Aragon-Vargas and Gross (cited Dugan (5)) state that the use of average power is of little use if your aim is to increase your vertical jump, instead the collection of peak power is necessary as this is by far the better indicator of vertical jump performance. A further study by Harman et al. (Cited Dugan) reported that peak power was very highly correlated with vertical jump performance, *r* 5 0.88, while average power had a much lower correlation, *r* 5 0.54, with vertical jump performance. Studies such as that by Alemany, Pandorf, Montain, Castellani, Tuckow and Nindl (7) gathered the average power output along with peak power due to the fact that their study design was interested in gathering data on 30 consecutive squat jumps and therefore gathering an average reading for the 30 squat test does seem feasible. The aim of the study was to evaluate across the spectrum of the anaerobic energy system (e.g., phosphogen system and anaerobic glycolysis). Specificity is the key when collecting data and the ability to determine when a study has any relevance, if your sole aim is for relevant data for improving maximal vertical jump then studies that have used protocols for measuring maximal peak power should only be considered.

Reporting of load intensity

The problems associated with the recording of accurate and reproducible squat 1RM between study's is wrought with differences such as squat depth (full, half, & quarter), free weight or smith machine, and differing kinematics due to the use of either free weights or smith machine. Other factors such as the familiarisation of the exercises can also affect the resulting 1RM results and add to this also that subjects may also have used belts, knee wraps and other lifting assistance apparatus. Dugan et al, suggest that the use of reporting optimal loads in the terms of bodyweights (see graph below). Does this give us sufficient grounds to abandon testing for 1RM in favour of bodyweight only? I think not, surely scientists can put together 1RM protocols that can be adhered to by sufficient numbers of studies that will yield a high enough correlation to allow for meaningful data across study populations. Testing protocols from in the trench coach's will differ very little from test to test if the protocols are left unchanged and therefore they will be able to produce good correlation of data from test to test.



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One further problem with the above method however may be that the method has omitted the athletes strength ability and when this method is used in conjunction with the method advocated by Boyle it shows that the 300lb footballer would be loaded with 120lbs in comparison to the negative 20lb score obtained by Boyle. The use of bodyweight percentage methods may result in excessive overload for many athletes and therefore I believe that the method that incorporates both the strength and bodyweight of the athlete will produce more appropriate results. It is always safer to start with lighter loads and then add greater loads if the athlete can handle the increase.

Instructions given to Athletes

Dugan states the importance of instructions and queuing advice given to athletes whilst executing squat jumps and how this can affect the relevance of cross study data. For example Stone et al, measured peak power and optimal loads from both static and dynamic jumps from a parallel squat position. On the other hand McBride collected data on peak power and optimal loads based on self determined squat positions. Dugan is correct that this does effect the reliability of cross study relevance of data. This should clearly tell scientists that protocols should be designed to clearly determine the methods, instructions and queuing necessary to allow for cross study reproduction of squat jumps that allows for high levels of correlation between data's collected.

Conclusion

It seems to me that the protocol suggested by Boyle may be the best starting point for anyone wanting to implement squat jumps into their training. However to maximise the full benefits of Boyles system I would also check with him regarding his methods and protocols for measuring 1RM and his technique, and instruction for performing squat jumps. As failure to follow these two important points could affect the reliability of his total system weight protocol.

The scientific community has some work to do in designing same across studies protocols and design before cross study correlations can be made to obtain relevant information. Until then I suggest that careful reading of each of the studies is required and the relevant information abstracted from it and tentatively put into practice.

Squat Jumps are effective for developing peak power and vertical jump performance but it is best to remember that research is in it's infancy and for that reason following the suggestions of Michael Boyle may be best as his methods are based upon in the trench research that has led to successful development of increased vertical jump performance in athletes (3-4 sets of 5 reps with 40% of total system weight)). One final piece of wisdom from him is if it does not look "elastic" then it is not right. This is one area of training where higher weight placed upon the bar may not lead to better gains, in fact it may only lead to excessive loads being placed upon the body that could result in injury.

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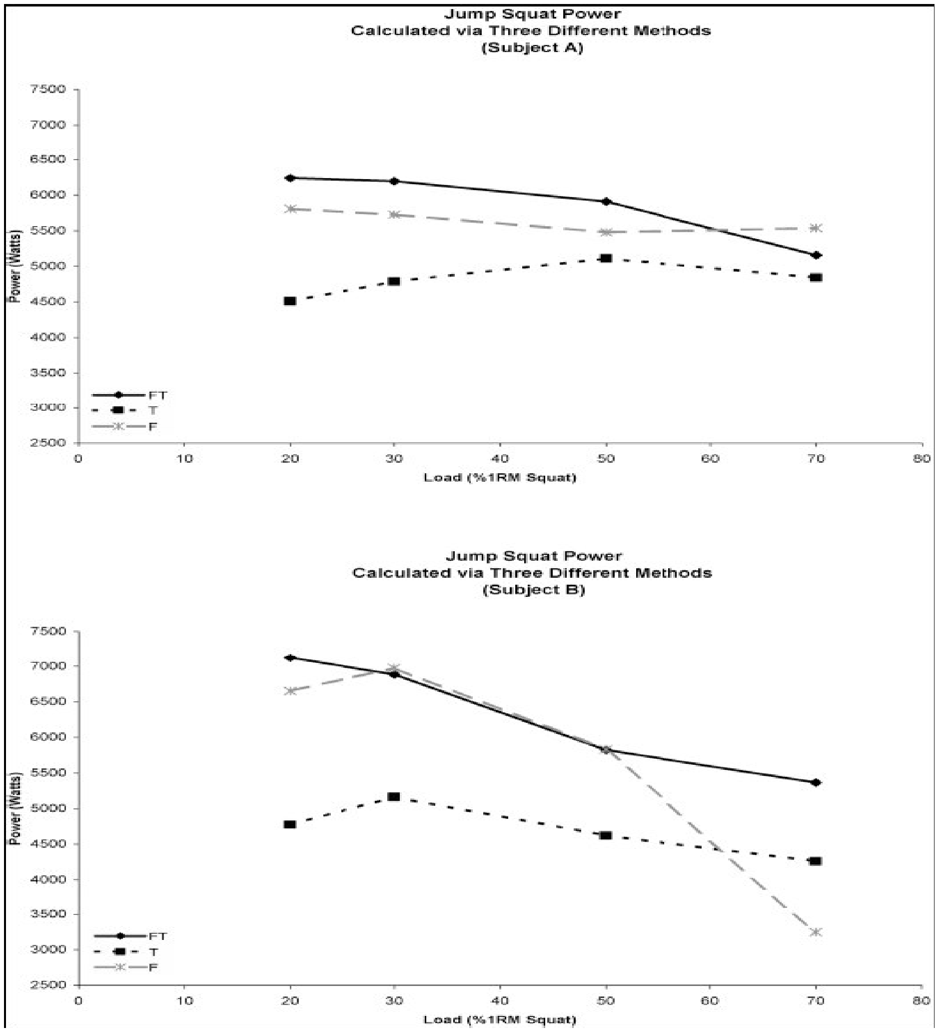
Jump Squat Power
Calculated via Three Different Methods
(Subject A)
Power (Watts)
Load (%1RM Squat)
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Jump Squat Power
Calculated via Three Different Methods
(Subject B)
Power (Watts)
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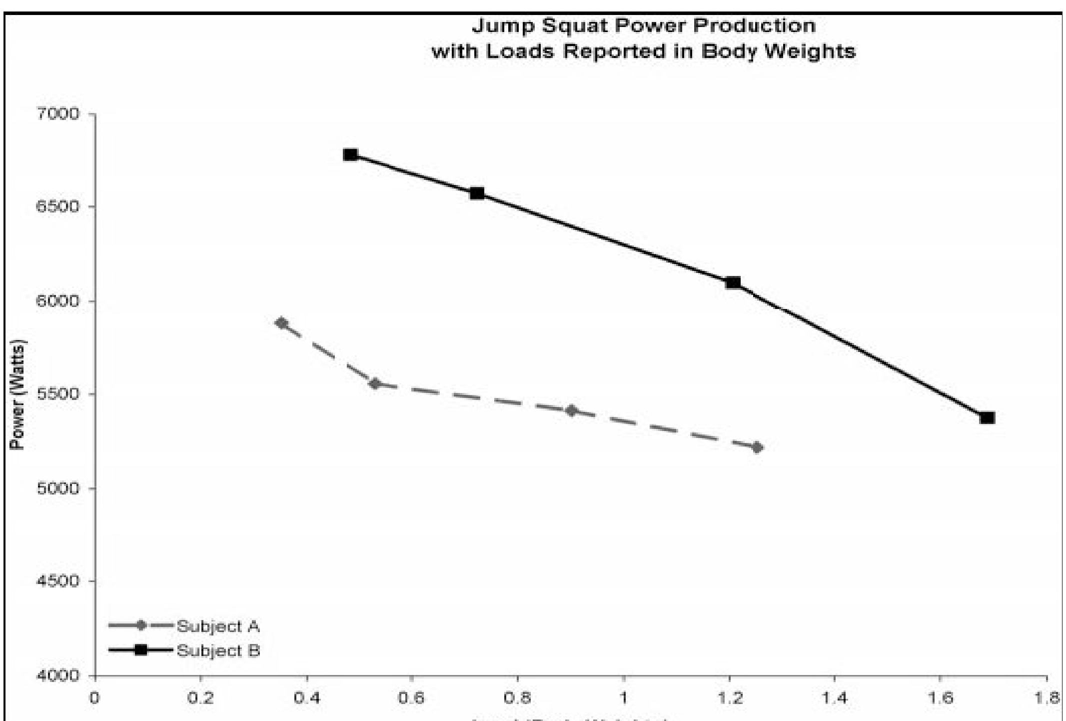
Jump Squat Power Production
with Loads Reported in Body Weights
Power (Watts)
Load (Body Weights)
Subject A
Subject B