

# Acceleration and gravity power: a concept for understanding total power output.

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*Keywords:* Vertical jumps, kinematic, force platform

## 1 Introduction

The quantification of the load-power relationship is useful to track changes in performance after training and to identify the load to be used. It is recommended that to improve power, athletes should use the load that maximizes power output. However, recent researches demonstrated that for some specific exercises, peak power presented only few variations through a wide range of load, meaning that whatever the load used the athlete produces near maximal power output [1, 3]. According to these results, the load used to maximize power may have less importance than previously claimed. However, performing a squat at 20% of the 1RM or at 80%, despite producing the same power output, results in a very different neuromuscular activity and according to the training specificity theory, working with 20% or 80% should not result in identical training objectives as well as neuromuscular adaptations.

During resistance exercise, the total force that is used to calculate power can be separated into two forces: the force of gravity and the force related to the system mass (body weight + bar weight) acceleration during movement. Similarly, total power output could be split into a power linked to the force of gravity (gravity power,  $P_g$ ) and a power linked to the system mass resulting acceleration (acceleration power,  $P_a$ ).

It may be that differentiating total power output into these  $P_a$  and  $P_g$  and noting their effects, results in a different interpretation of the load-

power relationship and therefore the loading and adaptational effects to muscle. The purpose of this study therefore was to note how differentiating power output into two components affected interpretation of loaded and unloaded counter-movement jump data.

## 2 Methods

Ten healthy men with a recreational sports background participated in this study (age  $26 \pm 4$  yrs; height  $1.80 \pm 0.05$  m; weight  $77 \pm 9$  kg). After a standardized warm-up, all subjects performed three unloaded (CMJ) and three 20 kg loaded counter-movement jumps (CMJ-20) on a force platform (Kistler, type 928A11) that was used to measure vertical GRF. A customised Labview application (Labview 8.5, National Instrument) specifically developed for the counter-movement jumps was used to calculate other mechanical parameters.

According to Newton's second law, system (body+mass) center of mass acceleration ( $a_{com}$ ) during vertical jumps is proportional to the net force ( $F_{net}$ ) applied which correspond to the difference between ground reaction force (GRF) and gravity force that have opposite directions.

$$F_{net} = m \cdot a_{com} = GRF - mg \quad \text{and} \quad GRF = m \cdot a_{com} + mg$$

The single integration of  $a_{com}$  can be used to calculate centre of mass vertical velocity ( $v$ ). Total power ( $P_{GRF}$ ) is the power of the the GRF and can be presented as the product of force and velocity and can be split, according to the

following equation, in two power components: the power of the system weight that is related to gravity (gravity power ;  $P_g$ ) and the resulting power that is related to center of mass vertical acceleration (acceleration power ;  $P_a$ ).  $P_a$  and  $P_g$  can be calculated by the following equations:

$$P_{GRF} = GRF \cdot v = (ma_{com} + mg)v = ma_{com}v + mgv = P_a + P_g$$

$$P_a = ma_{com}v \quad \text{and} \quad P_g = mgv$$

Peak values were calculated for the three powers during the ascending phase of both jumping conditions. A t-test for paired sample was used for the comparison of the two jumps.

### 3 Results and Discussion

The means and standard deviations of peak powers ( $P_{GRF}$ ,  $P_g$ ,  $P_a$ ) are presented in Table 1.

The comparison of CMJ and CMJ-20 has revealed that  $P$ ,  $P_a$  and  $P_g$  are not affected in the same way when load was increased. In fact, it appeared that the change in load had more influence on  $P_a$  and  $P_g$  than on  $P_{GRF}$ . In the present study, jumping with 20 kg changed more dramatically  $P_g$  (+9%,  $p < 0.001$ ) and  $P_a$  (-17%,  $p < 0.001$ ) than  $P_{GRF}$  (-6%,  $p < 0.05$ ). For some subjects  $P$  was almost the same in the two jumps, while both  $P_a$  and  $P_g$  were significantly different. Given these results it appears that  $P_a$  and  $P_g$  are more sensitive to changes in load than  $P$  is.

The findings of this study question the value of traditional power-load profiling and the use of these profiles in training load selection. Researchers have reported that in movements like the squat, squat jump and power clean, the change in  $P_{GRF}$  was relatively minor over a wide range of loads [1,3] highlighting that in these specific cases, profiling the P-load relationship may not be that important. Such lack of clarity around the load-power relationship has led scientists and practitioners to different schools of thought [2]. While some have suggested using lighter loads (<50% 1RM) to improve power output and athletic performance others have claimed that heavier loads were more efficient. There is currently no scientific evidence to suggest that one method is superior to another to improve maximal power, however, with the introduction of  $P_a$  and  $P_g$  concept, it appears that using light or heavy load should result in different training outcomes. Profiling  $P_a$ -load and  $P_g$ -load relationships could be more relevant for coaches to determine which amount of load they

have to use in their power training programme. Obviously, load selection should depend on sport characteristics and the relative importance of  $P_a$  and  $P_g$  during decisive actions.  $P_g$  training appears relevant when external force such as gravity force are dominant whereas  $P_a$  training would appear more suitable when resulting acceleration has to be emphasised. For example, in the power lifting  $P_g$  looks of greater importance because of the high work against gravity whereas in vertical jumps  $P_a$  may be more relevant as high vertical velocities need to be developed.

### 4 Conclusions

The introduction of the  $P_a$  and  $P_g$  concept should lead to new consideration about power output and the load to be selected to maximize muscle performance. Obviously, additional research on that topic needs to be achieved.

### 5 References

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Table 1. Peak values (mean±SD) for  $P_{GRF}$ ,  $P_g$  and  $P_a$  during CMJ and CMJ-20 and relative differences ( $\Delta$  %) \* $p < 0.05$  ; \*\* $p < 0.001$ .

	$P_{GRF}$ (w)	$P_g$ (w)	$P_a$ (w)
CMJ	4121±640	2093±250	2288±563
CMJ-20	3862±702	2284±281	1893±464
$\Delta$ %	-6%*	+9%**	-17%**