Mechanical Power Developed during Simulated Pull Movements in Weightlifting

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Abstract

Mechanical power outputs were measured during simulated pull movements in weightlifting to see how the mechanical power relates to the athletic performance. For this purpose, a dynamometer was newly developed for measuring force, velocity, work and power. The loads against the movements were provided by adding plates of various weights to the inertia wheel. Subjects pulled the wire which was wound around the axis of the inertia wheel. Mean velocity (MV), mean force(MF) and mean power (MP) were determined by dividing integrals of the instantaneous velocity, force and power curves, respectively, with time. Pull movement in weightlifting from the starting position (first pull) to the final pull (S－1) was divided into three components i. e., leg extension (S－2), hip extension (S－3) and shoulder shrug (S－4). Subjects were twenty-two Japanese weightlifters including eight elite and fourteen district level lifters. Mean values of MPs under the load of 15kgw were 1024.4, 999.9, 561.8 and 299.3w, respectively, when measured separately in the movement condition of S－1, S－2, S－3 and S－4. In each movement condition, MF－MV and MV－MP relations were obtained from measurements with different loads. MV decreased in a hyperbolic manner and MP showed a peak with increasing MF. In elite level lifters, both MV and MP were higher than those in district level lifters at an identical MF level. Statistically significant positive linear correlation (r=0.838, p<0.001) was observed between MP exerted during the S－1 movement and the athletic performance expressed as the total weight (snatch＋clean&jerk) recorded in competition. It is concluded that the mechanical power measured during the simulated pull movement in weightlifting with the present dynamometer is useful for evaluating, and therefore improving the athletic performance. Furthermore, this dynamometer is capable of providing the force - velocity characteristics during multi - articular movements of various body segments.

Key words : New dynamometer, mechanical power, simulated pull movement, weightlifting

Introduction

In human natural movements including those in sports, tension generated by muscle contraction is transferred to the external objects via bones and joint systems. Force working onto the external object varies both physically and physiologically according to the muscle lenght, the contraction speed and the mode of contraction etc.

For evaluating muscle strength, the use of dynamomerer has widely adopted, in which counter force of muscle contraction can be measured by controlling mechanical resistance in various ways[1, 2, 16, 19, 23]. (i. e., static, isotonic and isokinetic loading systems). In studies with these methods, the major interest has so far been focused on the mechanical characteristics of the muscle itself[15, 17, 22, 24, 26], since in these studies, the extermal force was measured under restricted condition in terms of the posture, the range and the velocity of joint motions.

Performance in the athletic sport might not be fully related to the mechanical characteristics of individual muscle determined by the methods mentioned above. Indeed, many factors affecting the length-tension, the force-velocity relations and the contraction modes of the muscles involved in the real movement might be so variable with time and from muscle to muscle that they can not be predicted from those obtained under specific loading conditions.

On the other hand, the vertical jump test[5, 6, 7, 8, 11]) has been widely accepted as the method to evaluate force, velocity, work and power during short explosive whole-body movement. However, it is thought that mechanical variables determined with the vertical jump tests do not necessarily represent the maxmum power of the subject, since the load on each muscle during the lift work against gravity is restricted by the subject's body mass.

In this study, we developed a new dynamometer for measuring force, velocity, work, and power under inertia loading condition during multi-joint, explosive movements. With this equipment, mechanical power outputs during pull movement in weightlifting were measured to evaluate the mechanical power related to the athletic performance, particularly aiming the future application of the dynamometer to improve the athletic performance in weightlifting.

Methods

Apparatus

A dynamometer "Power Processor" (Vain Co. Ltd., Tokyo, Japan) for the measurement of force, velocity, work, and power was newly developed (Fig. 1). Mechanical parts of the "Power Processor" consist of a rotary encoder, an electrical winder, a magnetic brake system, a load cell, and an inertia loading system. Time required for 1/100 rotation of the inertia wheel was measured by rotary encoder. Tension on the wire was measured by the load cell. The magnetic brake system and electric motor act as the stoppers of the rotation of inertia wheel and that of the winder of wire around the axis of inertia wheel, respectively. Load was given by adding plates of known weights to the inertia wheel, which were ranged from 0 to 25kgw, i.e., 50.70 to 311.98kg of equivalent mass, respectively.

As shown in the block diagram of Fig. 1, electrical signals from the rotary encoder and the load cell were sampled at every five milliseconds and stored in the IC memory card, then read by a personal computer (PC9801VM, NEC Co., Tokyo, Japan) through an interface and used for further analyses.

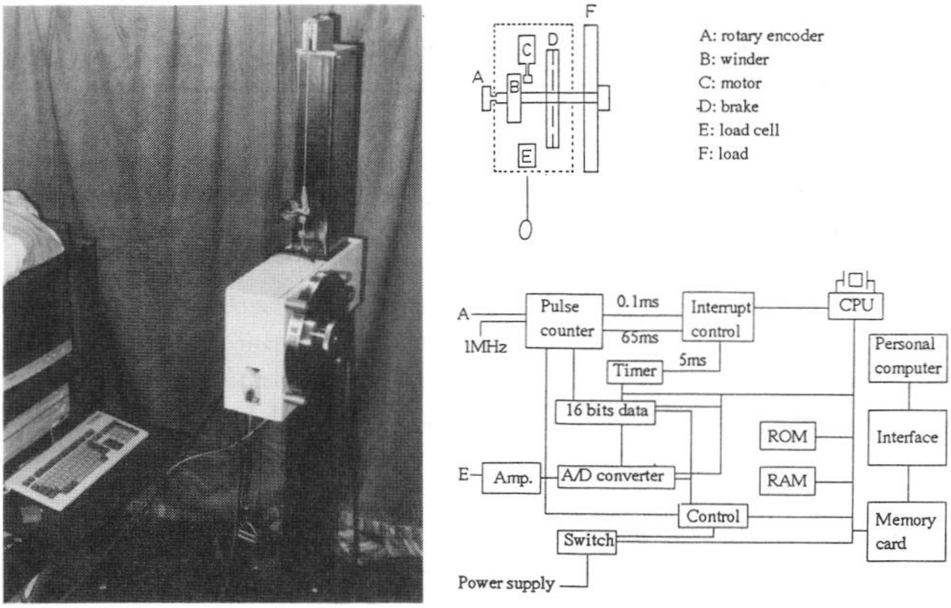


Fig. 1 Newly developed dynamometer "Power Processor" (left) and its structure and block diagram for mechanical measurements (right).

Procedures

Subjects pulled the wire which was wound around the axis of the inertia wheel via a pulley system, as shown in Fig. 2. Four kinds of simulated pull movement in weightlifting were performed : S − 1, the pull from the starting squat position to the final pull position in weightlifting ; the other three, the pull movements performed only by leg extension(S − 2), hip extension (S − 3), and shoulder shrug(S − 4), respectively (Fig. 4).

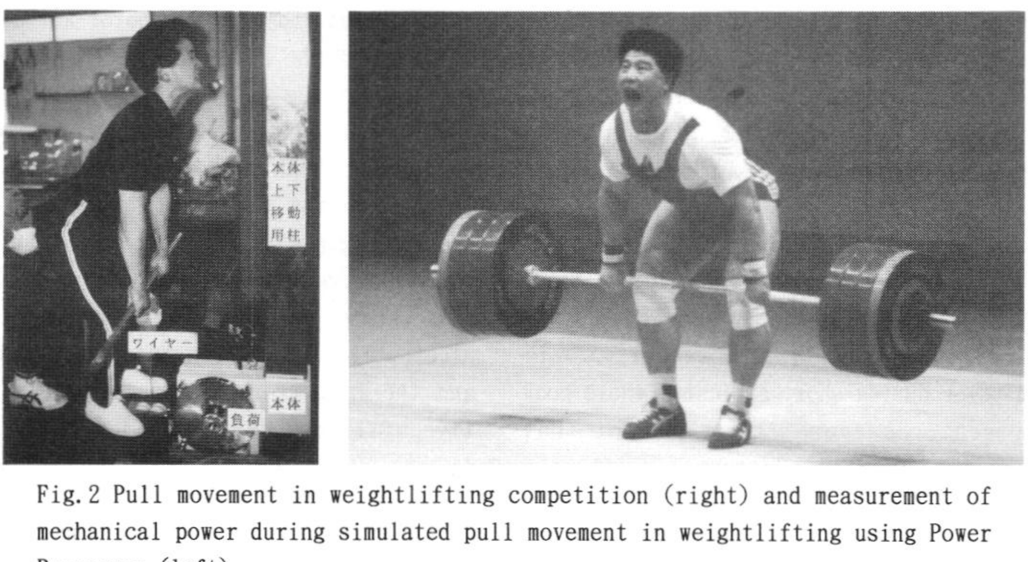
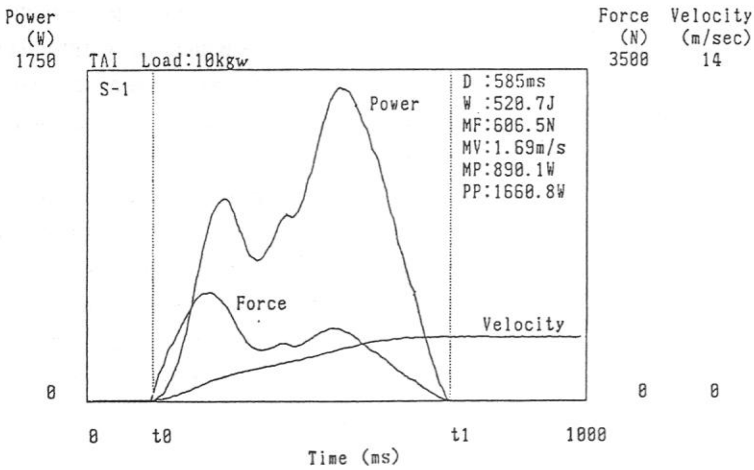


Fig. 2 Pull movement in weightlifting competition (right) and measurement of mechanical power during simulated pull movement in weightlifting using Power Processor (left).

Mechanical measurements

Velocity of the wire along its axis was calculated from the angular velocity of the inertia wheel recorded by rotary encoder. An instantaneous power curve was calculated by multiplying instantaneous velocity and force. As shown in Fig. 3, work (W) was determined by integrating power with respect to time, while mean force (MF), mean velocity (MV) and mean power (MP), were determined by dividing integrals of force, velocity and power, respectively, by time.



$$W=\int_{t_0}^{t_1}P(t)dt$$

$$MF=1/(t_1-t_0)\int_{t_0}^{t_1}F(t)dt$$

$$MV=1/(t_1-t_0)\int_{t_0}^{t_1}V(t)dt$$

$$MP=1/(t_1-t_0)\int_{t_0}^{t_1}P(t)dt$$

Fig. 3 Typical recordings of instantaneous velocity, force and power curves during simulated pull movement in weightlifting (S − 1). D:duration, W:work, MF:mean force, MV:mean velocity, MP:mean power, PP:peak power

Subjects

Subjects were twenty-two Japanese weightlifters including eight elite lifters (Seoul Olympic lifters, body weight mean ± SD : 69.0 ±15.2kg) and fourteen district lifters (six junior and eight senior lifters, body weight mean ±SD : 69.5 ± 10.2kg). Athletic performance expressed as the total best weight lifted (snatch+clean & jeak) per body weight were 4.23 ± 0.29kg/BW (mean±SD) for elite lifters and 3.23± 0.56kg/BW (mean±SD) for district lifters.

Results

Mean values of maximum MPs exerted in four sets of simulated movement by all subjects were 1024.4, 999.9, 561.8 and 299.3w for S − 1, S − 2, S − 3 and S − 4, respectively.

Fig. 4 shows instantaneous velocity, force, and power curves obtained from four simulated pull movements. Two peaks appeared in the in force and power curves during the movement of weightlifting pull(S − 1) and the leg extension(S − 2), which may reflect the double knee bending movement as used in the weightlifting technique.

Fig. 5 shows changes in MP with load for each movement condition. Maximum MPs were exerted under the loads between 5kgw and 15kgw in all movement conditions. Higher values of MP were observed in S − 1 movement than in S − 2, S − 3, and S − 4, condition. Higher values of absolute MP values were observed in elite lifters than in district lifters. In S − 1 movement, Mean(SD) values of MPs relative to body weight under the load of 10kg were 15.6

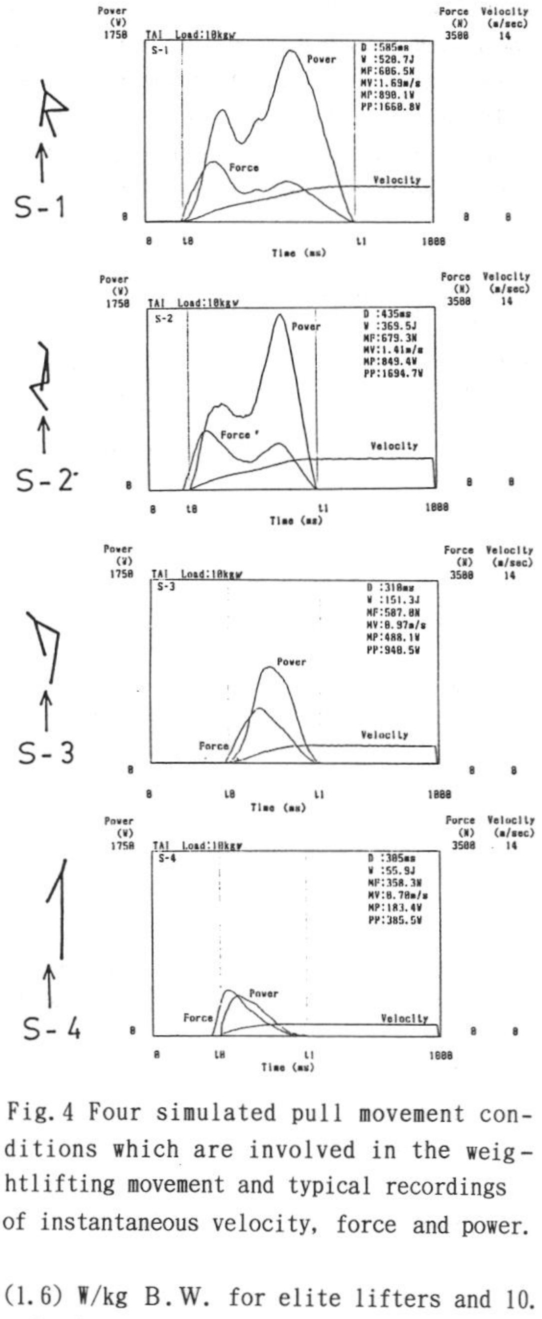


Fig. 4 Four simulated pull movement conditions which are involved in the weightlifting movement and typical recordings of instantaneous velocity, force and power.

(1.6) W/kg B.W. for elite lifters and 10.0 (1.7) W/kg B.W. for district lifters. MPs developed during S－2, S－3, and S－4 movements corresponded to 94%, 72%, and 43% of MP developed during S－1 movement, respectively.

In each movement condition, MF－MV and MF－MP relations were obtained from measurements with five different inertia loads as shown in Fig. 6. With increasing MF, MV decreased in an apparently hyperbolic manner and MP seemed to show a peak. In elite lifters, both MV and MP were higher than those in district lifters at an identical MF level.

Fig. 7 shows the relationship between MP and athletic performance in weightlifting. The athletic performance were assessed as the total weights lifted by snatch and clean & jerk in the same competition. Statistically significant positive linear correlation was observed between MPs developed in all simulated pull movements and the athletic performance. However, the correlation was stronger in S－1 movement than in other three movement conditions.

Discussion

Many kinds of ergometry have been developed for measuring the physiological capability of humans during high intensity and short duration exercises. Stair climbing[5, 20] and Wingate test[3, 21] have been widely accepted for evaluating the human anaerobic capacity during repetitive muscle contraction. Power measured with such methods however, might be different from that exerted by an explosive movement performed by a strong muscle contraction lasting for less than a second. Furthermore, in protocols taken by the above methods, essential parameters for calculating power such as force and velocity are not directly measured.

Special equipments with an isometric or isokinetic loading system[1, 15, 22, 23, 24, 26] (e. g., Cybex dynamometer) have so far been widely used for evaluating either muscle strength or power developed during single muscle contraction lasting for less than a

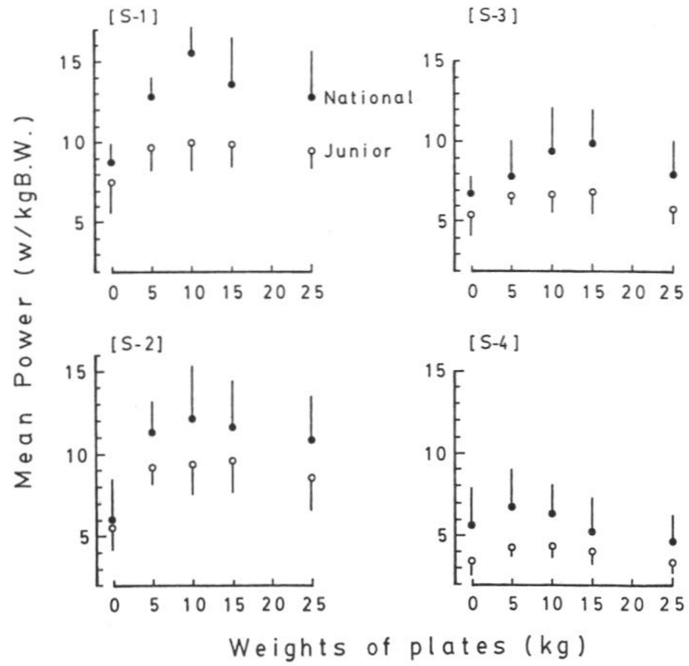


Fig. 5 Changes in mean power(MP, watts/kgBW) with load for each movement condition.

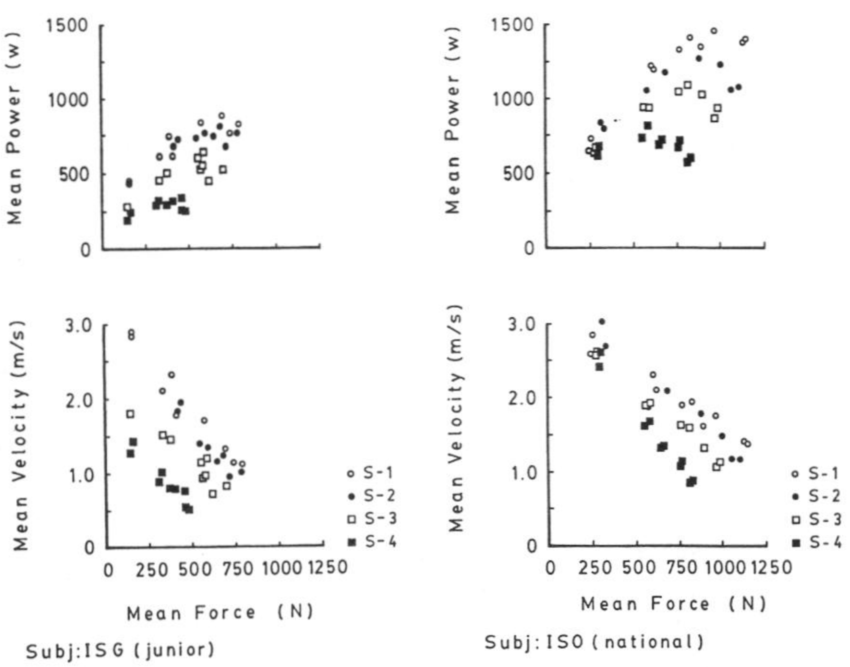


Fig. 6 Mean force (MF)-mean velocity(MV) relation (lower) and MF-mean power (MP) relation (upper) obtained from measurements with five different inertia loads for elite (right) and district (left) lifter groups.

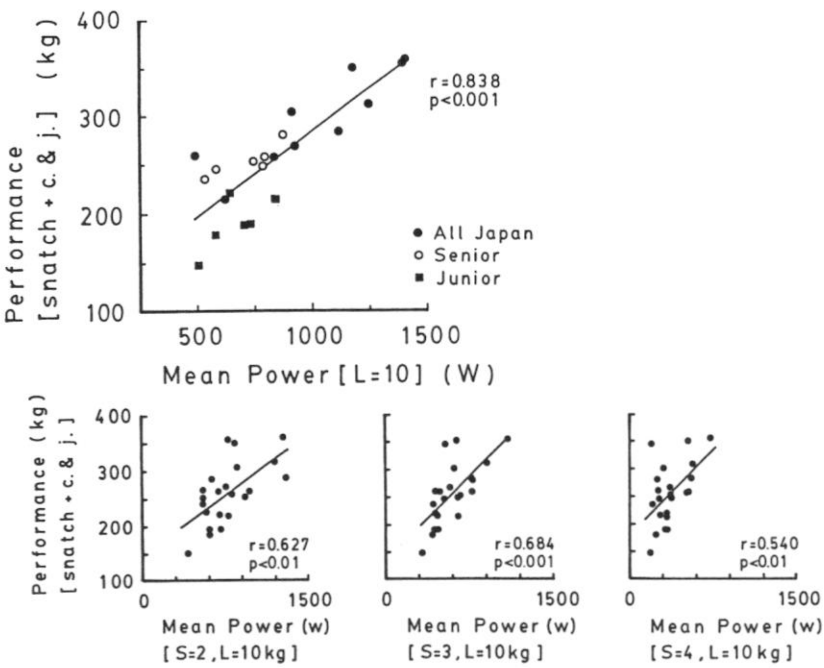


Fig. 7 Relationships between mean power (MP) and athletic performance (snatch+clean&jerk) in weightlifting. In the lower panels, values are plotted irrespecive of the performance level (elite and district).

few second. With these iquipments, however, mono-articular movements such as flexion or extension of elbow or knee joint were studied for elucidating the characteristics of muscle itself from externaly measured mechanical variables.

Vertical jump test[5, 6, 7, 8, 11], on the other hand, have veen commonly used for evaluating the power developed during multi-articular movement. In this method, it is difficult to obtain any information about the characteristics of power in relation to velocity or force, because load is restricted by the subject's body mass against gravity. In other words, the power developed during the vertical jump does not always reflect the maximum potential of the subject.

In the newly developed dynamometer "Power Processor", force and velocity were directly measured for calculating power, and also, work, force, velocity and power exerted during an explosive multi-articular movement could be obtained under various inertia load conditions.

Mean power recorded in S − 1 condition showed higher value than that reported in a maximum acceleration pedalling[5, 21], but lower than the instantaneous power exerted during weightlifting movement which calculated from high speed film analysis of the barbell elevation speed[10] (ranging from ca. 1400W to 4000W) and vertical jump (ca. 3000 to 4000W)[12].

In the elite group, maximum mean power was developed under the load of 10kgw in S − 1 and S − 2 conditions, on the other hand, maximum values in S − 3 and S − 4 condition was reached under the loads of 15kgw and 5kgw, respectively (Fig. 5). This difference may be caused by the difference in force-velocity characteristics of the major muscle groups responsible for each movement. The mean force-mean velocity and the mean force-mean power relations appeared to be similar to those obtained from mono-articular movement[16]. There have been few studies that have drawn the force-velocity-power relations from human movements involving two or more joints[13, 25]. Recently, evidence for the validity of describing the force-velocity relationship for a multi-segment movement (vertical jump) with varying loads has been presented[18]. It has been argued that the optimum load (specific matching of force and velocity) for maximum power generation is not unique, but depends on various multi-articular movement conditions.

Mean and peak power developed during the simulated pull movement (S－1) were significantly correlated to the athletic performance in weightlifting (Fig. 7). In the field of sports sciences, few study have described the relationship between the athletic performance and the mechanical parameters obtained from dynamometer measurements. Moreover, in the biomechanical researches on the Olympic style weightlifting, attention has been mainly paid to calculate the mechanical work and power[9] with limited application of those to the performance evaluation[4]. Our results suggest the importance of selecting the mechanical valuables related to the movements particular for a given kind of sport, for evaluating the athletic performance.

Relative values of work liberated during S－2, S－3 and S－4 movements to that of S－1 movement were 81.6%, 56.1% and 23.1%, respectively, in the elite weightlifters, and 70.5%, 65.0% and 27.1%, respectively, in the district level weightlifters. These imply the segmental contribution[14] to the total work liberated during a simulated whole pull movement(S－1). In the elite weightlifters, contribution of leg extension (S－2) was larger and that of hip extension (S－3) was smaller than those, respectively, in the district weightlifters. Work made during S－1 movement significantly correlated to work made during S－2, S－3 and S－4 movements in both elite and district groups. These observations suggest that the leg extension movement plays a crucial role in determining the amount of work liberated during S－1, and therefore the performance in the weightlifting.

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