A METHOD FOR KINETIC POWER MEASUREMENT FOR JUMPING USING VIDEO ANALYSIS TECHNIQUES

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INTRODUCTION

The purpose of the research is to validate video analysis techniques developed for the prediction of peak power (PP) at takeoff for both vertical and horizontal jumps. The significance of the study is to utilize standard video analysis techniques to measure kinetic power. In order to validate the accuracy of the power measures, force plate measurement is used to substantiate the video analysis results. The value of the method enables the researcher to utilize the advantages of video analysis for kinetic measurement in all jumping movement applications. The methods may also be adapted to motion requiring power measures, however this study was restricted to jumping. The approach utilizes two methods, the inverse dynamics approach using kinematic measures for the velocity of the center of mass (V, CM) taken from video analysis. Kinetic force (F) and power (P) are calculated based on the kinematic video analysis. The second method, direct dynamics, uses ground reaction forces (GRF) to calculate velocity (V) and power (P). The force platform measurement system is recognized in the literature as being the most accurate kinetic measure of force and power (Vandewalle et al., 1987, Harman, 1991) and is therefore used to validate the video measures through statistical correlation. Based on the correlation, a prediction equation is developed, based on the differences between the video power measures and force plate measures for both vertical and horizontal jumps. The equations provide an accurate prediction of the muscular power output during the jump takeoff.

METHODOLOGY

Nineteen subjects (10 males, nine females) performed maximal vertical and horizontal jumps from a force plate while being videotaped from a lateral view. The best of three trials, based on the vertical and horizontal distances jumped were chosen for videotape analysis.

The Peak 2-Dimensional Analysis system was used to measure the jumping motion, videotaped at 60 Hz. A maximal shutter speed of 1/1000 s was used to minimize blur when filming with the VHS camera. Standard anatomical landmarks and anthropometric measures were used for the video calculations (Plagenhoef, 1983). CM displacements and velocities were measured during the take-off phase of the jump and the data was presented in both a graphical and raw data format for export and further analysis. The power analysis is based on the changes in velocity of the CM during the take off phase of the jumps. A computer software program was written to calculate power using CM data in the formula $F * T = MV_2 - MV_1$ to produce power outputs for each frame interval on the video (Figure 1). The PP calculation is based on the point in time when F and V combine to produce maximal peak power.

The AMTI force plate was used to record ground reaction forces (GRF) for the best of three maximal vertical and three maximal horizontal jumps. The power software package formula (Figure 2) was used to calculate power (PP) in Watts. Horizontal jump, resultant velocities and take off angles were calculated using the vertical (Fz) and horizontal (Fy) GRF's. Resultant PP for the horizontal jump was calculated using the formulae in Figure 2.

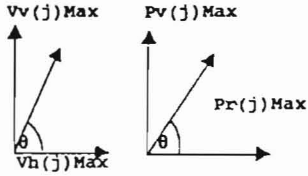
VERTICAL JUMP

$$\Delta Vv(j) = Vv(j) - Vv(i)$$

$$Fv(j) = \frac{m.\Delta Vv(j)}{t}$$

$$Pv(j) = Fv(j) . Vv(j)$$

HORIZONTAL JUMP



$$\theta = \arctan\frac{Vv(j)\,Max}{Vh(j)\,Max}$$

$$Pr(j)\,Max = \frac{Pv(j)\,Max}{\sin\theta}$$

Where:

Vv(j)Max=Peak Vertical velocity
Vv(j)=Vertical Velocity
Vh(j)Max=Peak horizontal velocity
M=Subject's mass
Pv(j)=Vertical power
Pv(j)Max=Peak vertical power
Pr(j)Max=Peak resultant power

$\Delta Vv(j)$ = Changes in velocity
Fv(j)=Net vertical force

t=Sampling time
θ= Angle of takeoff

Figure 1. Video power calculations.

VERTICAL JUMP

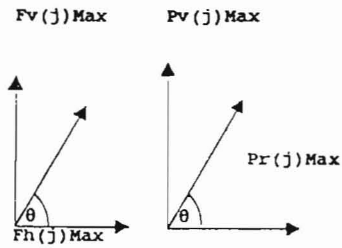
$$\int_{i=0}^{j} Fv(J) . dt = \int_{i=0}^{j} M.a.dt$$

$$Fv(j) . t = M.\Delta Vv(j)$$

$$Vv(j) = \sum_{i=0}^{j} \frac{Fv(j) . t}{M}$$

$$Pv(j) = Fv(j) . Vv(j)$$

HORIZONTAL JUMP



$$\theta = \arctan\frac{Fv(j)\,Max}{Fh(j)\,Max}$$

$$Pr(j)\,Max = \frac{Pv(j)\,Max}{\sin\theta}$$

Where:
M= Subject's mass
Fv(j)=Vertical Force
Vv(j)=Vertical Velocity
t=Sampling time
Pv(j)=Vertical Power

Fv(j)Max=Peak Vertical velocity
Fh(j)Max=Peak horizontal velocity
θ=Angle of Takeoff
ΔVv=Change in velocity
Pv(j)Max=Peak vertical Power
Pr(j)Max=Peak resultant power

Figure 2. Force plate power calculations.

The PP results from the video power analysis on both the vertical and horizontal jumps are validated by correlation to the PP result on the force plate analysis. Linear regression equations were developed to determine a valid measure of power using the video analysis recordings of the vertical and horizontal jump (Table 1).

Table 1. Peak power results for vertical and horizontal jumps.

Subject	Vertical Jump Video Peak Power (VPP) (W)	Vertical Jump Force Plate Peak Power (FPP) (W)	Horizontal Jump Video Peak Power(VPP) (W)	Horizontal Jump Force Plate Peak Power (FPP) (W)
1	4747.7	4846.9	4770.4	3131.6
2	4769.3	5531.3	5470.6	3211.5
3	3841.4	3955.0	3921.2	2652.0
4	5019.9	4663.0	6301.3	3335.7
5	5260.2	5020.4	4229.1	2887.0
6	3884.1	3886.8	5543.5	2679.7
7	4558.8	4011.0	4613.5	2930.7
8	4174.5	4134.8	4975.3	2162.9
9	2831.9	2928.8	6176.2	2928.7
10	3418.4	3953.7	5025.2	3174.4
11	3800.1	4278.6	5156.1	3779.3
12	4764.1	4924.1	4977.5	3075.4
13	5583.5	5221.5	4327.2	2535.6
14	4420.6	5197.8	4495.4	2289.2
15	3151.1	3816.6	4126.4	1927.3
16	4568.8	5325.0	3878.3	2200.9
17	2093.6	2540.7	4703.1	2063.1
18	3720.1	3700.0	4632.6	2503.4
19	4511.4	4526.8	4232.7	2441.0
Mean	4164.2	4340.2	4819.0	2732.0
SD	871.7	805.3	687.0	491.5
r	0.88	0.88	0.63	0.63
Peak Power Prediction Equation	PVP=0.8169 PVU + 938.33 where: PVP=Peak Vertical Power PVU=Peak Vertical Power Uncorrected		PRP=0.395 PRU + 829.9 where: PRP=Peak Resultant Power PRU=Peak Resultant Power Uncorrected	

DISCUSSION

The application of video analysis techniques has been largely limited to kinematic measures of displacement velocity and acceleration. In order to expand the applications of video analysis accurate predicted measures are often required for kinetic analysis. Kinetic measures of force generally use the F=ma relationship including the second order differentiation to produce acceleration. This power analysis software system utilizes the inverse dynamics approach to calculate force from velocity data. The force calculation is combined with velocity to provide a prediction for peak power. Special consideration must be given to the gravity force component when considering changes in velocity to calculate net force. The accuracy of the video measures and power prediction is limited by digitizing error, video image quality and picture rate. Consideration should be given to the minimization of error in the measurement process. A linear regression equation has been developed to adjust for the differences between the force plate and video power results (Table 1). The correlation relationships indicate the degree to which the two measures relate and the equations provide a reasonably accurate prediction of the leg power developed during vertical and horizontal jumps. The application of three-dimensional video analysis for multi planar, motion, power analysis is also a possibility using the prediction formula. Validation of the power measures could also be enhanced using a larger number of subjects.

CONCLUSIONS

Predicted power measurement using standardized video analysis provides a valuable measurement technique which may be applied to a variety of activities other than jumping. The method outlined in this research deals strictly with vertical and horizontal jumping power, however further human motion applications need to be developed and validated for measurement accuracy using video analysis techniques.

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