THE APPLICATION OF BIOMECHANICS IN SPORT EQUIPMENT INNOVATION

Tzyy-YuangShiang

Department of Athletic Performance
National Taiwan Normal University

Sport equipment plays a key role for the performance in all kinds of sports games. Sport competition is not only the skill competitions among athletes and coaches but also the design competitions among the equipment companies. The basic principles of sport science and biomechanics should be applied in sport equipment innovation.The new equipment which enhance muscle strength and explosive power come out one after another. In the recent years, more and more biomechanics theories were applied in the strength training equipment.A new developed training method is demonstrated in this paper.Passive leg press training wasdeveloped based on the concepts of the stretch-shortening cycle and the benefits of high muscle contractionvelocity.Thus,these muscle groups accomplished both concentric and eccentric isokinetic contractions in a passive, rapid, and repetitive manner.The results suggest that jump performance, speed, and muscle power significantly improved after PLP training.Applying biomechanics for sporting goods innovation is a promising approach to integrate academic research and industrial which can increase industrial competitiveness and open more doors for biomechanics research.

KEY WORDS: Sport equipment, training, trend.

INTRODUCTION: As an old Chinese saying: A workman must first sharpen his tools to do a good work(551–479 DC, Confucius).工欲善其事，必先利其器（論語衛靈公篇）。Sport equipment plays a key role for the performance in all kinds of sports games. Sport competition is not only the skill competitions among athletes and coaches but also the design competitions among the equipment companies (Hung, 2009). However, the R&D direction of most equipment companies still remains consumer-oriented, low-pricing, appealing-design. In order to develop new functional sporting goods, we have to thoroughly understand the basic principles of sport science and biomechanics, then apply the concepts in sport equipment innovation.

In the early development, sport games and physical education were the major applications of biomechanics. The research then focused on movement analysis,the purposesare to enhance sport performances and to reduce sport injuries (Hay, 1978). Besides, movement analysis provides a solid base for physical education. In order to search for more detail of the parameter affecting the quality of human movements, biomechanics is with a further step to study the human muscular-skeletal system and how they work (Winter, 1990). Plus physical therapy, orthopedics and sport medicine studies, biomechanics isongoing search for the principles inside human body as well as the impacts on human performance. When technology continuously advanced, the technical devices were applied into sport training and competitions. This development influences the performances significantly. Thus the researches of biomechanics shift from movement analysis and muscular-skeletal system into sport equipment study. At the moment, the complete sport biomechanics covers the biomechanics of human muscular-skeletal system, human movements and performances analysis, and sports related equipment design(Figure 1)(Shiang, 2009).

Footwear is a typical equipment which biomechanics can contribute significantly. Footwear research has made substantial progress, since there were numerous studies focus on footwear in the last 30 years (Nigg, 2006). In addition to footwear, there are all kinds of fitness equipment in current market. The new equipment which enhance muscle strength and explosive power come out one after another. In the recent years, more and more biomechanics theories were applied in the strength training equipment. Passive training is a typical model which required applying biomechanics for sporting good innovation which is demonstrated in this paper.

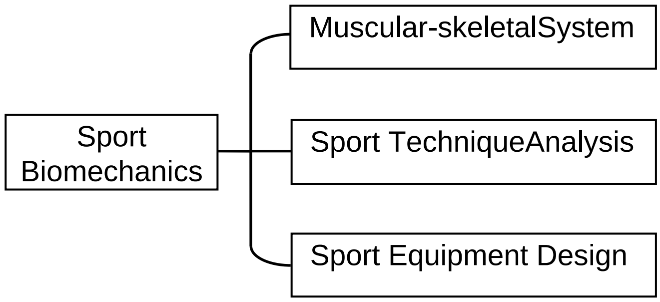

Figure 1: Sport biomechanics – research scopes

METHOD: Passive leg press (PLP) training wasdeveloped based on the concepts of the stretch-shortening cycle and the benefits of high muscle contractionvelocity (Figure 2). PLP training enables lower limb muscle groups to apply a maximum downward force against a platformmoved up and down at high frequency by an electric motor(Liu, 2013). Thus,these muscle groups accomplished both concentric and eccentric isokinetic contractions in a passive, rapid, and repetitive manner. This study investigates the effects of 10weeksPLP training at high and low movement frequencies on jumping performance, speed, and muscle power. We selected 30 college students who had not performed systematic resistance training in the previous 6 months, and randomly divided them into three groups (n=10), including traditional resistance training at a squat frequency of 0.5 Hz, PLP training at a low frequency of 0.5 Hz, and PLP training at a high frequency of 2.5 Hz.The participants' vertical jump, drop jump, 30-m sprint performance, explosive force, and SSC efficiency were tested under the same experimental procedures at pre- and post-training.

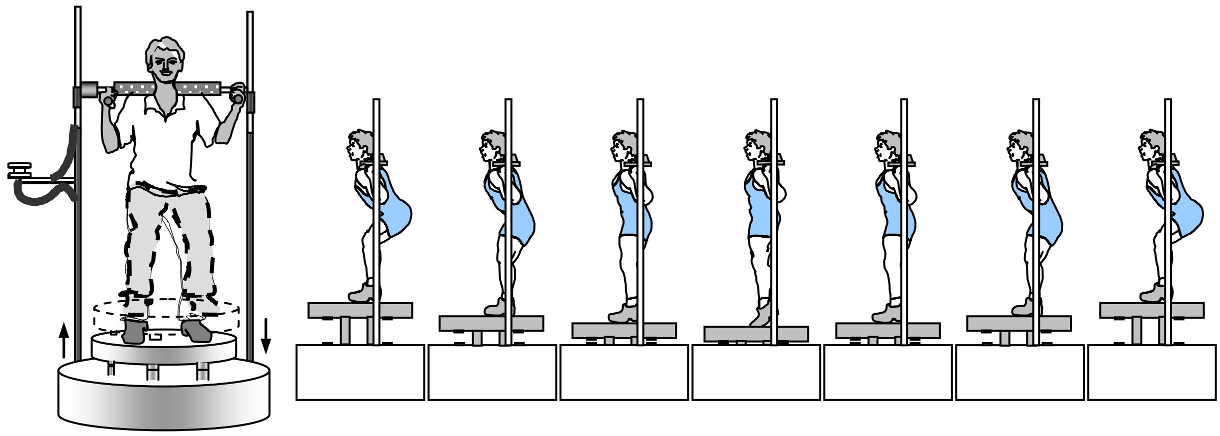

Figure 2.The PLP training machine; (L) the front view, (R) the lateral view.

The PLP training machine is an electric motor-powered specialized muscle training equipment. The platform moves upward and downward and, in contrast to traditional resistance training, enables rapid movement. During PLP training, the trainee's shoulders were restricted from upward vertical motion by a stationary bar, enabling them apply maximum downward force to the moving platform using their lower limbs muscles. Thus, the trainee's muscles perform both concentric and eccentric isokinetic contractions in a passive, rapid, and repetitive manner throughout the PLP training session.

RESULT & DISCUSSION: Results reveal that high-frequency PLP training significantly increased participants' vertical jump, drop jump, 30-m sprint performance, instantaneous force, peak power,and SSC efficiency($p < .05$). Additionally, their change rate were substantially superior to those of traditional resistance training ($p < .05$) (Table 1). The low-frequency PLP training significantly increased participants' vertical jump, 30-m sprint performance, instantaneous force, and peak power($p < .05$). However, traditionalresistance training only increased participants' 30-m sprint performance and peak power($p < .05$). The findings suggest that jump performance, speed, and muscle power significantly improved after 10 weeks of PLP training at high movement frequency. Therefore, the new PLP training method provided positive effects among participants with no previous resistance training experience after a 10-week training period. Muscle training with high contraction velocity in passive way is one of the major approaches to increase muscular power and speed.

Table 1. Comparison of jump performances after 10 weeks of training(M ± SD)

Group	Jump	Pre-training (cm)	Post-training (cm)	Change rate (%)
Traditional	vertical	66.00±8.41	67.56±9.93	1.90±2.85#
	drop	63.56±8.20	64.56±9.70	0.70±2.83#
PLP-low	vertical	61.44±2.60	65.00±3.35*	3.30±2.79
	drop	60.78±5.17	62.00±2.35	1.30±5.36#
PLP-high	vertical	60.00±3.72	65.10±3.95*	3.56±2.52
	drop	56,78±5.25	62,78±3.04*	6.00±3.75

* indicatesa significant difference between pre- and post- training results ($p < .05$)
# indicatesa significant difference from that of the PLP-highgroup($p < .05$)

In addition to the study of training effect on colleague students, the trainingdevice was also used to train elite athlete. An elite Taekwondo athlete who qualified for Olympic Games participated in this study(Wang, 2005). The subject completed 7-wk PLP training with high velocity and high motion frequency movement.The subject's one repetition maximum (1RM) and isometric maximal voluntary contraction (MVC) for the half squat was measured by Cybex Smith Press and PLP training machine.A whole body reaction measurement machine,an accelerometer and dummy were used to measure kicking velocity and impact acceleration of specific kicking movements. The result of this study indicated thatkicking velocity of the right leg Roundhouse kicking significantly increased After 7 wk of PLP training($p < .05$). The impact acceleration of four types of single kicking movement were also significantly higher compared to pre-testing ($p<.01$). The significant reduced in movement time of two types of continuous kicking movements was observed ($p < .01$, $p < .05$) and both movements also significantly increased impact acceleration ($p<.01$). The strength of 1RM and MVC had a significantly greater improvement after PLP training($p<.01$).The results of this study clearly demonstrated that a 7- wkPLP training was an efficient method for training elite athletes to improve specific kicking performance and general strength performance.

Table 2. Pre-test, mid-test, and post-test results of movement velocity and impact acceleration of single attack kicking.

Performance	Testing Occasions		
	Pre	Mid	Post
Movement Velocity (m/sec)			
RRK	3.56±0.15*	3.49±0.16	3.66±0.16*
LRK	3.52±0.19	3.54±0.16	3.72±0.31
RRKS	2.48±0.14	2.37±0.17	2.62±0.26
LRKS	2.58±0.06	2.62±0.15	2.63±0.09
RBK	3.05±0.15	2.99±0.30	3.13±0.17
Impact Acceleration (g)			
RRK	132.19±3.97*	131.17±4.49*	139.25±1.12*
LRK	112.67±6.71*	111.89±6.05	117.97±6.75*
RRKS	103.59±2.28	106.37±1.94	107.78±2.09
LRKS	102.14±1.94**	103.31±2.90	105.85±2.71**
RBK	114.22±4.62**	115.96±5.83	132.80±4.34**

indicatesa significant difference ($p < .05$), ** indicatesa significant difference ($p < .01$)

CONCLUSION: Sporting goods should be designed based on biomechanical principalsto provide the optimum effect.Applying biomechanics for sporting goods innovation is a promising approach to integrate academic research and industrial which can increase industrial competitiveness and open more doors for biomechanics research.The new concepts and more young researchers joining the field will provide additional exciting development and progress in the future.

REFERENCES:

Hay, J.G. (1978). The Biomechanics of SportsTechniques, Prentice Hall.

Hung, T.M., Tang, W.T. &Shiang, T.Y. (2009). Acase study of integrated sport sciences for anOlympic archerJournal of Medical andBiological Engineering 29(4): 164-171.

Liu, C., Chen, C.S., Ho, W.H., Fule, R.J., Chung, P. C. &Shiang, T.Y. (2013). The effects of passive leg press training on jumping performance, speed, and muscle power. *Journal of Strength and Conditioning Research*.27(6), 1479–1486.

Nigg, B. (2006). New ideas and concepts in sport shoe development. *XXIV ISBS Symposium 2006, Salzburg – Austria.*

Shiang, T.Y. (2009). The trend of sport biomechanics,*Chinese Journal of Sport Biomechanics*，1, 52-55.

Wang , H.H., Liu, C., Chu, M.Y., Ho, W.H. &Shiang, T.Y. (2005).Effects of passive repeated plyometric training on specific kicking performance of elite Olympic taekwondo player.*International Society of Biomechanics XXth Congress.Cleveland , U.S.A.*

Winter, D.A. (1990). Biomechanics and motor control ofhuman movement (2nd ed). Canada: John Wiley &Sons, Inc.