RPM^2

Remote Performance Measurement and Monitoring

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Abstract

The RPM^2 device is a state-of-the-art wireless, remote monitoring, pressure sensing device that is used for sports performance enhancement. The device measures several variables of interest to athletes, trainers, and coaches who can use these variables to correct mechanics, promote correct form, and potentially prevent injury, and when injury occurs, possibly speed recovery. RPM^2 can measure body weight, pressure distribution and range-of-motion of lower extremities using four pressure transducers and a 9 axis sensor embedded in a shoe insert. The device offers 3D tracking capabilities, wireless communication, and a secured user interface through Android/IOS phone applications.

RPM^2 has developed technology that will serve to enhance human performance. Performance enhancement in athletics, specifically with runners, is the company's primary mission. Running performance is improved through gait analysis feedback. Sensors, embedded in shoe inserts monitor the distribution of pressure on the soles of each foot. A 9 axis sensor is embedded in a microcontroller in each insert, creating a gyroscope. This effectively measures range of motion of the lower extremities. Measurements of pressure distribution and range of motion provide evaluative data relating to gait and bilateral equivalency.

Problem Statement / Introduction

Gait analysis is a very important component of competitive and recreational running performance. However it is often a last option when analyzing performance, and completed only after injury has taken place. Preventative gait analysis should be a critical component of performance analysis, as it could be used to optimize form, efficiency, energy expenditure, and to potentially decrease injury risk (1, 2, 4). The problem is that gait analysis requires expertise, expensive equipment, and a large amount of time. This is a matter of great inconvenience for the runner with no visible injury or noticeable problem with technique, and is the main reason gait analysis is often used only to correct injury, and not preventatively. Gait analysis provides critical detail needed to prevent injury in athletes. A career can be prolonged, or even saved, through recognition of improper mechanics during gait analysis. Forces created during running must be absorbed by the joints, and any flaw in running mechanics can cause excessive stress on the joints (2, 3). Preventing this excessive wear-and-tear is the key to a long, successful running career.

Proper mechanics will also increase performance by increasing running efficiency. Using the most efficient way to get from the start to the finish line decreases the caloric demand, spares glycogen, and allows the runner to maintain a lower heart rate, respiratory rate, and oxygen uptake for a given workload. Mechanics are key to success in all distances of running events,

though improper mechanics during long distance runs will have an increasingly detrimental effect as the runner continues to train and stress their joints. Proper mechanics and technique will also lead to increased strength and power through achievement of bilateral equivalence (4, 6, 8). A properly designed strength and conditioning program (9) can be developed from data that can be provided by RPM^2, such as when fatigue is occurring over the course of the run, and which side of the body tends to fatigue more rapidly.

Gait analysis is an important component of analyzing running performance. It is necessary, and will aid in determining how to correct mechanics to optimize running efficiency/economy, and to prevent injury and prolong career (5, 7). Gait analysis is expensive and not practical, and is often an overlooked variable that could help increase performance.

Proposed Solution

RPM^2

Remote Performance Measurement/Monitoring, or RPM² is a product that can bring gait analysis to runners without the need for expensive, time-consuming laboratory equipment that requires an expert in order to test and analyze. RPM² represents breakthrough technology to enhance running performance and potentially prevent injury. Running performance is improved through gait analysis feedback. Sensors, embedded in shoe inserts monitor the distribution of pressure on the soles of each foot. A 9 axis sensor is embedded in a microcontroller in each insert, creating a gyroscope. This effectively measures range of motion of the lower extremities. Measurements of pressure distribution and range of motion, relayed to an Android or IOS phone application, provide evaluative data relating to gait and bilateral equivalency. Distribution of pressure on the sole of the foot tells the runner (or coach) important information regarding gait. The distribution of pressure can be tested at various phases of a run. Information regarding the change in pressure distribution over the course of a run provides valuable feedback regarding how fatigue may impact gait. This information can be obtained simply by running with the device/insert and linking the data with a smartphone application. This eliminates the need for expensive, time-consuming gait analysis, and provides feedback essential to the success and longevity of the runner.

RPM² analyzes range of motion in the joints of the lower body. Five movements/exercises, including ankle dorsiflexion, knee extension, hip flexion, hip extension, and partial squat, are performed while the insert is in the shoe. Twenty repetitions are performed with each leg, and the RPM² system uses a gyroscope to provide detailed information regarding range-of-motion. This information is designed to help coaches determine strength/flexibility deficits, and to develop strength and conditioning exercises necessary to help achieve bilateral equivalence (7, 9).

Validity Testing Results

To determine if RPM² can function as a viable replacement for laboratory gait analysis and joint range of motion testing, the device underwent validity testing at Texas A&M University Corpus Christi. Subjects wore the device while undergoing gait analysis using the gait analysis plug-in component of the Vicon 3D motion analysis system.

Vicon T-series, using Nexus and Polygon software, is considered the clinical standard in gait analysis (10). AMTI force plates were calibrated and synchronized to indicated pressure

distribution during different phases of walking gait. This pressure distribution was compared to the distribution reported by RPM².

Joint range-of-motion (ROM) was measured by a goniometer, and through video analysis. Subjects were asked to perform the RPM² recommended exercises while wearing the device, three times a week for a period of 4 weeks. The exercises are standardized by RPM², and are included in the subject dashboard transmitted to the phone by the device. The ROMs measured by the goniometer and through video analysis of the hip, knee, and ankle joints were compared with the ROMs reported by RPM². A repeated measures ANOVA/MANOVA test was used to analyze the pre/post test results at each joint, as well as the data reported by RPM2 at each joint compared to the measurements obtained by goniometry and video analysis.

No significant differences in pressure distribution were found (measured at various phases of gait) between the RPM² and the laboratory gait analysis. This indicates that the RPM² can accurately predict pressure distribution at various phases of gait.

Although the validation study was not designed to indicate whether the device would increase flexibility/ROM of the lower body joints, a significant increase in ROM in the hip and ankle was found, when using the device and performing the exercises over a period of only four weeks. ROM increases were observed during hip extension, hip flexion, and in ankle dorsiflexion.

Conclusion

RPM² is a breakthrough technology that can enhance athletic performance. Data resulting from validation of the device suggest that even short periods of time using the device will lead to increases in ROM, which translates to an increase in flexibility and the ability to increase production of force in the given joint. With an increase in ROM, the increased torque and force produced in a given joint during running will lead to increases in performance.

The ability of the device to reproduce gait analysis, similar to that obtained by more expensive methodologies, makes this product unique, and an essential tool for athletes striving to improve performance, to potentially decrease risk of injury, and to prolong their athletic career. Pressure sensing during different phases of the run allows for the measurement of gait patterns for the duration of the exercise and hence allows for analysis of fatigue on performance metrics. Achievement of bilateral equivalence through the implementation of proper training techniques, inclusive of corrective exercises to facilitate improvement in mechanics, can be achieved through frequent monitoring using RPM².. The correction of improper mechanics, and training, to decrease fatigue, are important outcomes that are not usually available to the recreational athlete. With RPM² more athletes have the ability to gain insight into their gait patterns and gain an edge in performance.

The ability to achieve bilateral equivalence, correct improper mechanics, increase performance, potentially prevent injury and prolong career are extremely valuable to every athlete. RPM² gives a competitive edge to its users, and can provide the feedback necessary to take an athlete to the next level.

Appendices

Appendix A – Author disclosure

Dr. Kelly Brooks is an Assistant Professor and Biomechanist at Texas A&M University Corpus Christi. The author was not compensated to write this paper, and no conflict of interest is present.

Appendix B – References

1. Berger W, Dietz V, Quintern J. Corrective reactions to stumbling in man: neuronal co-ordination of bilateral leg muscle activity during gait. *The Journal of physiology.* 1984;357(1):109-125.
2. Dietz V, Quintern J, Boos G, Berger W. Obstruction of the swing phase during gait: phase-dependent bilateral leg muscle coordination. *Brain research.* 1986;384(1):166-169.
3. Häkkinen K, Alen M, Komi P. Changes in isometric force□and relaxation□time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiologica Scandinavica.* 2008;125(4):573-585.
4. Häkkinen K, Kallinen M, Linnamo V, PASTINEN UM, Newton R, Kraemer W. Neuromuscular adaptations during bilateral versus unilateral strength training in middle□aged and elderly men and women. *Acta Physiologica Scandinavica.* 2003;158(1):77-88.
5. Häkkinen K, Kraemer WJ, Kallinen M, Linnamo V, Pastinen U-M, Newton RU. Bilateral and unilateral neuromuscular function and muscle cross-sectional area in middle-aged and elderly men and women. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 1996;51(1):B21.
6. Impellizzeri FM, Rampinini E, Maffiuletti N, Marcora SM. A vertical jump force test for assessing bilateral strength asymmetry in athletes. *Medicine and science in sports and exercise.* 2007;39(11):2044.
7. Kuruganti U, Parker P, Rickards J, Tingley M, Sexsmith J. Bilateral isokinetic training reduces the bilateral leg strength deficit for both old and young adults. *European journal of applied physiology.* 2005;94(1):175-179.
8. Kuruganti U, Seaman K. The bilateral leg strength deficit is present in old, young and adolescent females during isokinetic knee extension and flexion. *European journal of applied physiology.* 2006;97(3):322-326.
9. Rutherford O, Jones D. The role of learning and coordination in strength training. *European journal of applied physiology and occupational physiology.* 1986;55(1):100-105.
10. Vicon Gait Analysis Plug-in; http://www.vicon.com/applications/gait_analysis.html
11. Young W, James R, Montgomery I. Is muscle power related to running speed with changes of direction? *The Journal of sports medicine and physical fitness.* 2002;42(3):282.