New model shows importance of feet, toes in body balance

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Researchers are using a new model to learn more about how toe strength can determine how far people can lean while keeping their balance.

The results could help in building robotic body parts that will closely imitate human movement, and might lead to a new generation of advanced prosthetics.

Hooshang Hemami, professor of electrical and computer engineering at Ohio State University built a complex computational model of the human foot to look at the role of the feet and toes in determining the body's movement and balance.

Many studies concerning human balance have emphasized the legs and upper body while ignoring the feet, he said.

Hemami is one of a handful of researchers who are analyzing how manipulating toe strength can affect human balance.

"In order to reduce the complexity of the problem, the feet are often either neglected or modeled using simple shapes that don't really give full credit to the importance of feet," Hemami continued.

Hemami and a colleague, Laura Humphrey, designed a computer model of a body and foot which assigned four different sections to represent different parts of the foot, while assigning the body one section. This allowed Hemami and Humphrey to focus primarily on the pressure of the feet and toes as they manipulated the forward motion of the body.

Hemami and Humphrey's work was published in a recent issue of the *Journal of Biomechanics*. The researchers performed simulations of static balance and forward leaning in the computer-modeled body, and compared the results to those observed in the scientific literature.

Static balance is when a subject stands either straight or at a certain angle, and is able to remain stabilized in that position with the entire surface area of the bottom of the foot on the ground. The computer model can perform forward leaning indefinitely, but human subjects will experience muscle fatigue eventually, explained Hemami.

The model that Hemami and Humphrey built allowed them to produce results that supported the findings of balance shown in real subjects. They conducted tests for three different cases: static balance in healthy subjects, static balance in subjects with diminished toe strength, and forward leaning in healthy subjects.

In order to have the model mimic a subject with diminished toe strength, Hemami and Humphrey weakened one of the sections in the computer-modeled foot, which represented a muscle located just above the big toe. This muscle helps control the foot's arch, which provides support to the body while standing.

Results indicated that in a healthy person, toes became increasingly important as the person leans forward.

As the computer-modeled body leaned forward, the pressure underneath the toes increased significantly, and the pressure underneath the heel decreased in a similar fashion.

When the same tests of static balance were performed on the computer-modeled body with diminished toe strength, the pressure underneath the toes remained at zero. Initially, the pressure underneath the heel was significantly higher than in the healthy subject, and as the body leaned forward, the pressure underneath the heel only decreased by half the amount that it did in the healthy subject.

The maximum angle that a healthy computer-modeled body could lean forward from the waist without its heels lifting off the ground was nearly 12 degrees from vertical. The model with diminished toe strength could only lean forward nearly 10 degrees.

The computer model supports past studies on real people, Hemami explained. One discrepancy: his computer model was able to lean forward 12 degrees without lifting its heels, while real people were only able to lean two-thirds as much -- 8 degrees.

"This discrepancy could be psychological – that people do not feel comfortable using their maximum theoretical range of motion," said Hemami.

Hemami's colleague Laura Humphrey was one of his doctoral students, and she has since graduated from Ohio State.

"Now that we have a reasonable computer model, we hope to explore, in the future, the sensory apparatus and other functions of the toes in diverse human activities," Hemami said.

He will be collaborating with Ian Alexander, professor of orthopaedics at Ohio State, in the near future.

In the future, Hemami wants to model the human spinal cord and develop a mathematical system that can determine the level of reaching and pushing required for certain tasks. Hemami uses the example of how much pressure one should administer to hold an egg in your hands without dropping or crushing it.

"My hope is that my work will inspire construction of robotic models of various body parts that can move similarly to the human body. If you can make a robot or computer model kick a soccer ball like a soccer player, we will have a better understanding of how various parts of the body work during movement. Then, perhaps, you can build an artificial spinal cord that could help the handicapped," Hemami said. "Attaching a robotic spinal cord to the outside of someone who is handicapped could help muscle development."

"We try to model what muscles do, which may help to develop more advanced prosthetics, so we have something better to offer people who need them," Hemami explained.

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