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Artificial balancer – Supporting device for postural reflex

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ABSTRACT

The evolutionarily novel ability to keep ones body upright while standing or walking, the human balance, deteriorates in old age or can be compromised after accidents or brain surgeries. With the aged society, age related balance problems are on the rise. Persons with balance problems are more likely to fall during their everyday life routines. Especially in elderly, falls can lead to bone fractures making the patient bedridden, weakening the body and making it more prone to other diseases. Health care expenses for a fall patient are often very high. There is a great deal of research being done on exoskeletons and power assists. However, these technologies concentrate mainly on the amplifications of human muscle power while balance has to be provided by the human themself.

Our research has been focused on supporting human balance in harmony with the human's own posture control mechanisms such as postural reflexes. This paper proposes an *artificial balancer* that supports human balance through acceleration of a flywheel attached to the body. Appropriate correcting torques are generated through our device based on the measurements of body deflections. We have carried out experiments with test persons standing on a platform subject to lateral perturbations and ambulatory experiments while walking on a balance beam. These experiments have demonstrated the effectiveness of our device in supporting balance and the possibility of enhancing balance-keeping capability in human beings through the application of external torque.

1. Introduction

Recently, postural reflex attracts interest from many researchers due to the coming aged society [1,2]. In biomechanics, balance is an ability to maintain the center of gravity of a body within the base of support with minimal postural sway as defined in [3]. It is the ability to resist the disrupting gravitational force. Elderly people gradually lose this ability due to various factors like sensory deterioration, concentration capacity decrease, weakening brain performance, muscles, etc. It is reported that the three sensory modalities relevant for balance, that is, proprioception, vestibular organs and vision decline in old age [4,5]. Also, the number of Purkinje cells in the cerebellum diminishes which causes increased tremor and body sway preventing smooth movements [6]. The reaction time is longer and the muscles become weaker. Since walking and balancing require a lot of concentration, it is difficult to carry out other tasks simultaneously as reported in [7]. In case of accident victims or people after brain surgeries, parts of the brain or the nervous system are damaged and balance-keeping ability is impaired. An excellent review on the balance recovery process of stroke patients is found in [8].

Patients with balance problems are prone to falls even while carrying out their everyday life routines. In case of hip joint fractures the patients become bedridden which often leads to other diseases. Medical costs for bedridden patients are very high. Preventing falls in everyday life would be a great contribution to society. Persons with balance impairments use tools like canes, crutches, walkers, joint stiffening orthoses, etc. These tools usually reduce the number of degrees of freedom. A great deal of research is done on exoskeletons and power assists like those described in [9–11]. However, all of these projects concentrate only on the muscle power amplification, not on the balance itself. Since biped walking is a combination of locomotion and balance, balance assistance is also important in exoskeletons. This paper proposes a balance support device for elderly or persons with postural reflex impairments.

In order to support balance, we use a flywheel attached to the body to externally apply counter-torque against the disrupting gravitational torque to the human body.

There are inverted gyro-pendulum, bicycle or mono-cycle balance controls using flywheels, for example [12]. However, applying the same principle to the human body is much more challenging. The human body is made of soft tissue and a rigid attachment of a flywheel is difficult.

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When designing a controller, the human balance control system, whether functional or impaired, must be taken into account.

In contrast to our research, gyro stabilizers that use mass rotating at constant speed are tested as human balance support.

The device we propose in this paper is purely non-invasive. It uses the rotational action/reaction principle of the flywheel attached to the human body through a tight and stiff corset. We have developed a feedback control algorithm for applying rotational torque to counter balance the body against disrupting torque, that is consistent with and compliments to human innate postural reflex.

We carried out upright stance and ambulatory experiments to prove the usefulness of our device and algorithms. In the upright stance experiments, the subject wearing our device stood on a flat surface. A sudden and short lateral displacement of the base resulted in balance disruption. Our device has been shown to assist the person in balance-keeping. In ambulatory experiments, the subject was walking on a balance beam. During ambulation, our device was supporting the lateral balance. The results show that our device reduced the range of body sway and other parameters during both upright stance and ambulatory experiments.

2. Posture reflex and support device

2.1. Balance-keeping as feedback control

A person about to lose his lateral balance, usually uses his arms to regain equilibrium as shown in Fig. 1a. Also, the movement of the upper body relative to the lower body plays a big role, but here

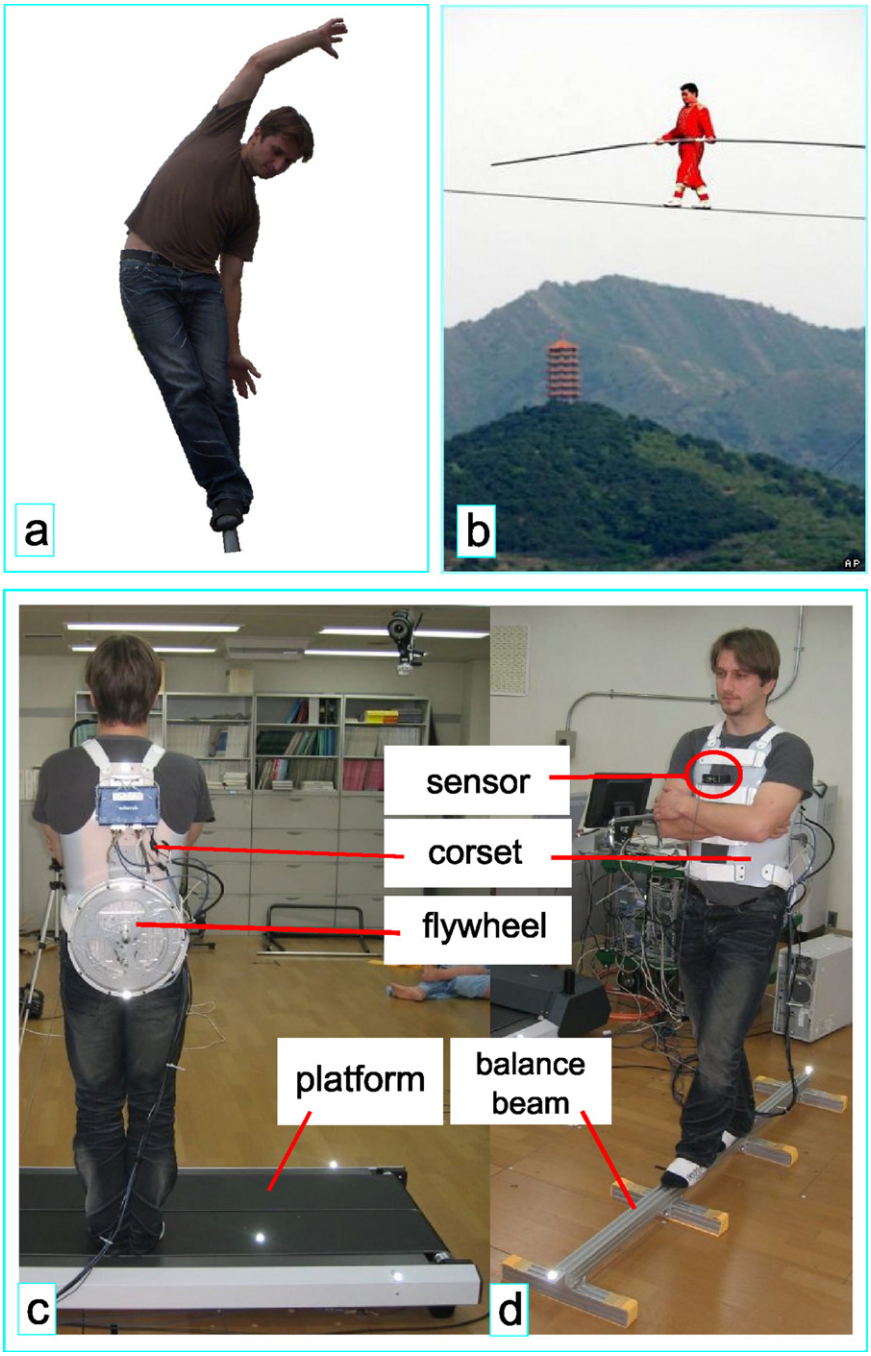

Fig. 1. (a) Balancing with arms, (b) tight wire act using a long pole, experiments with flywheel: (c) upright stance on a platform, (d) ambulation on balance beam.