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(19) **United States**(12) **Patent Application Publication**
Shahinpoor(10) **Pub. No.: US 2006/0240953 A1**(43) **Pub. Date: Oct. 26, 2006**(54) **HUMAN LOWER LIMB PERFORMANCE
ENHANCEMENT OUTFIT**(76) Inventor: **Mohsen Shahinpoor**, Albuquerque, NM
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V. Gerald Grafe, esq.**P.O. Box 2689****Corrales, NM 87048 (US)**(21) Appl. No.: **11/115,731**(22) Filed: **Apr. 26, 2005****Publication Classification**(51) **Int. Cl.****A63B 25/08** (2006.01)**A63B 21/02** (2006.01)(52) **U.S. Cl.** **482/77; 482/121**(57) **ABSTRACT**

The present invention comprises a user-friendly, soft and resilient, biomimetic (mimicking biological entities) lower limb support outfits that can be worn externally by people to improve and enhance lower limb, legs and knees performance in sports, daily dynamic activities and medical rehabilitation/physical therapy. More specifically, the present invention relates to an outfit, which allows a portion of the upper limb's quasi-static weight and dynamic weight due to impact forces to be excluded from being transmitted to the lower limb, legs, quadriceps and hamstrings muscles and knees by directly transmitting them to the ankles, footwear and/or the ground, through soft elastic columnar quasi-legs that are equipped with smart biomimetic materials such as shape memory materials and artificial muscles such as synthetic and/or ionic polymeric muscles and provide lower limb support function by buckling and bending in accordance with the dynamic maneuvering of the user. The said lower limb performance enhancing outfit is encapsulated by user-friendly fabric means for easy wear. The upper portion of the outfit can be in the form of a sports short worn by the user and encapsulating the buttocks support plates.

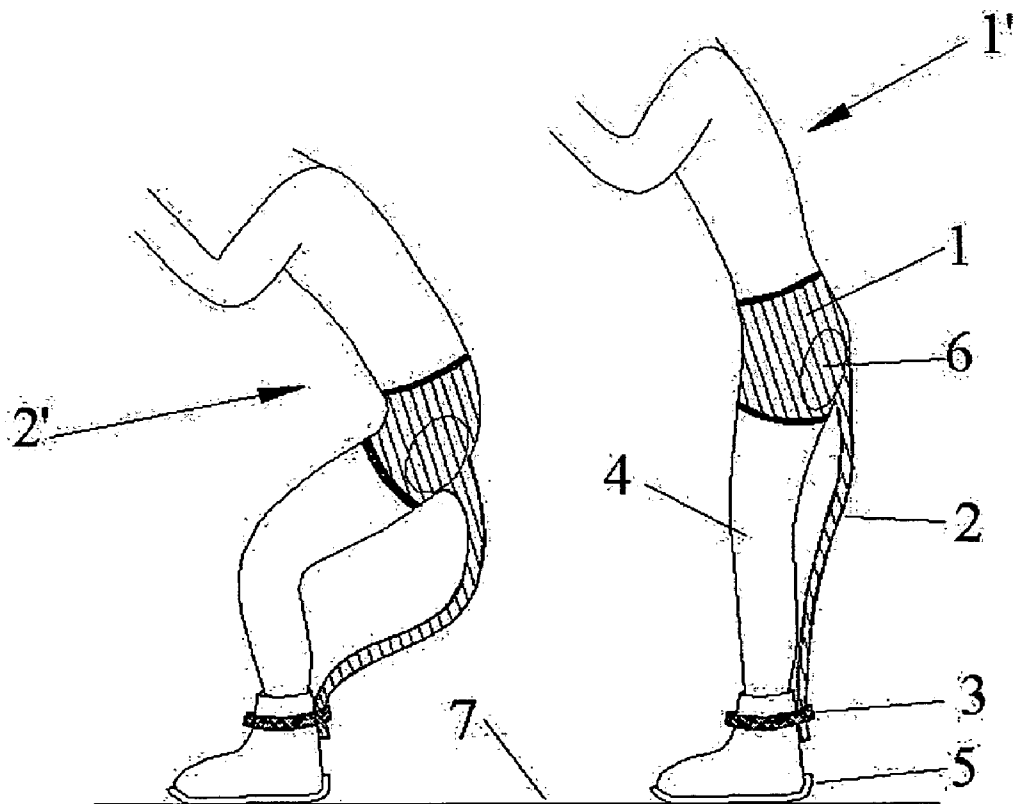


Figure 1

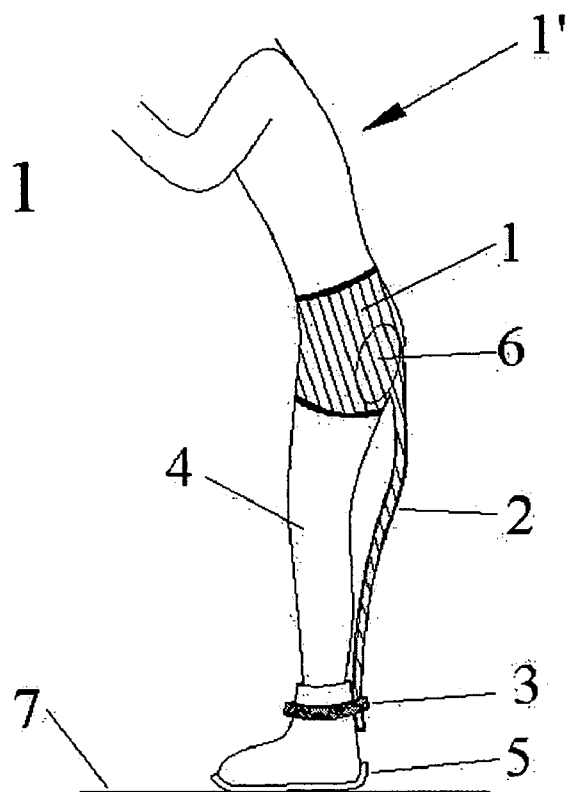


Figure 2

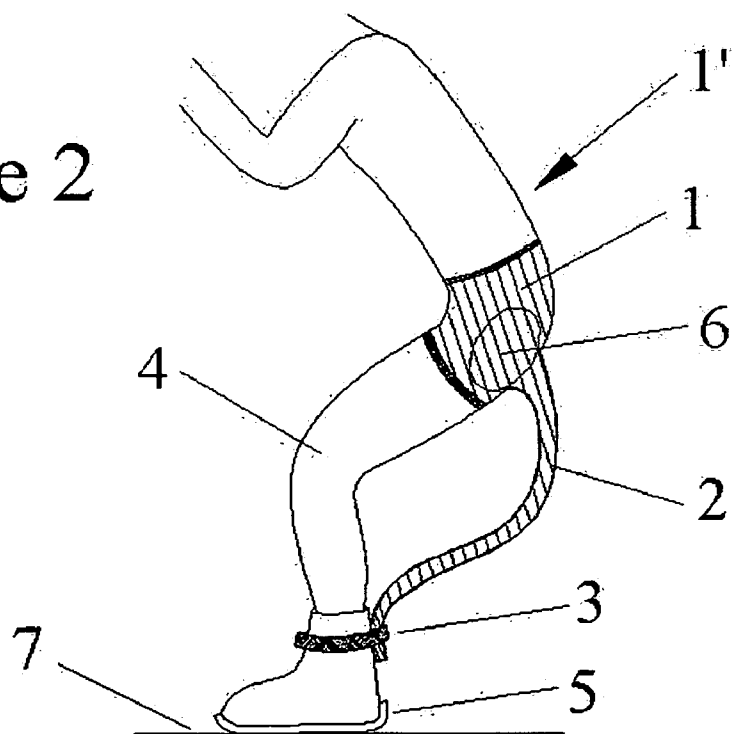


Figure 3

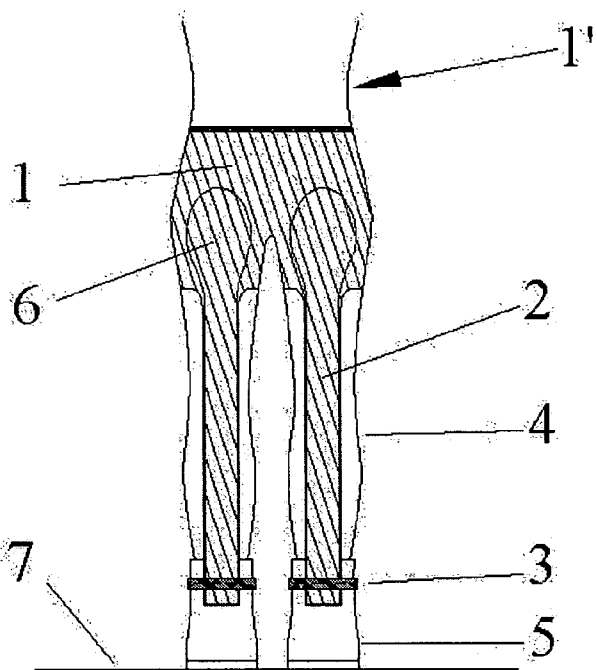


Figure 4

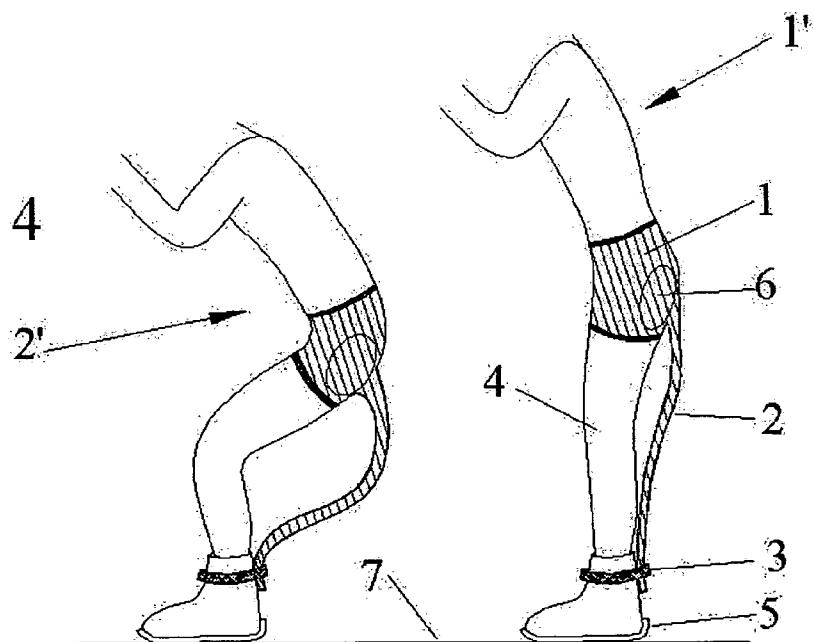


Figure 5

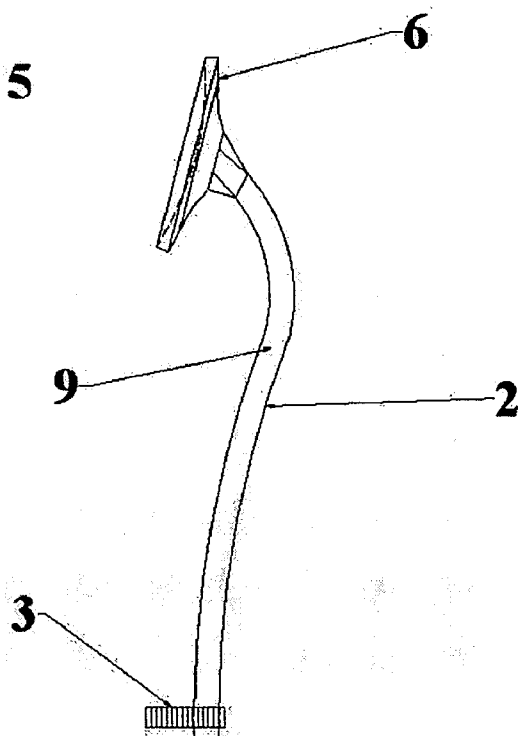


Figure 6

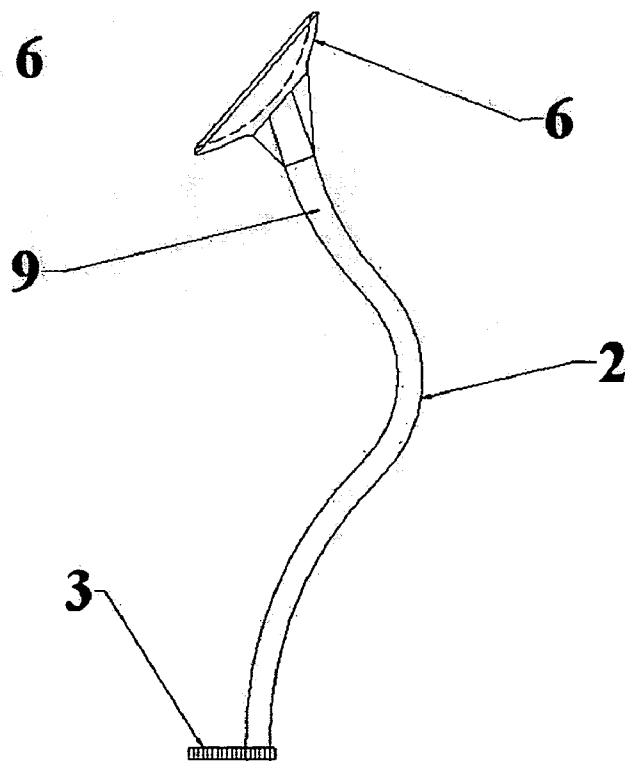


Figure 7

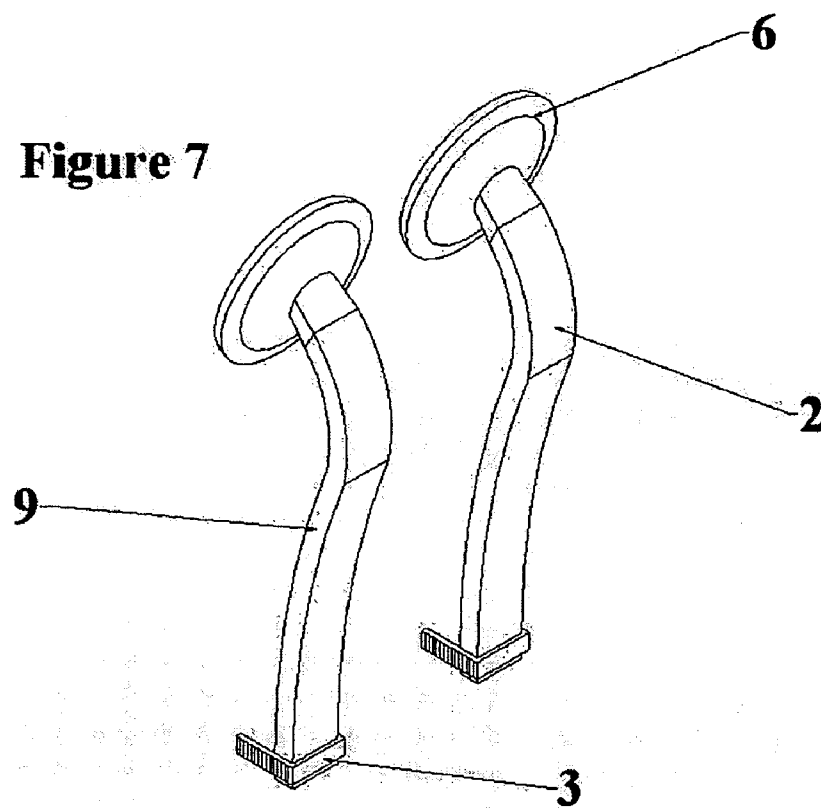


Figure 8

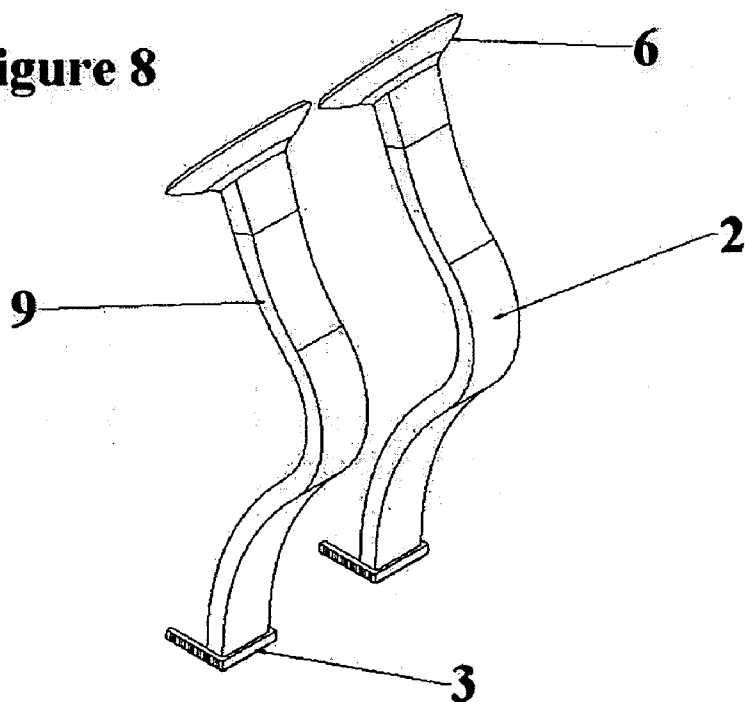


Figure 9

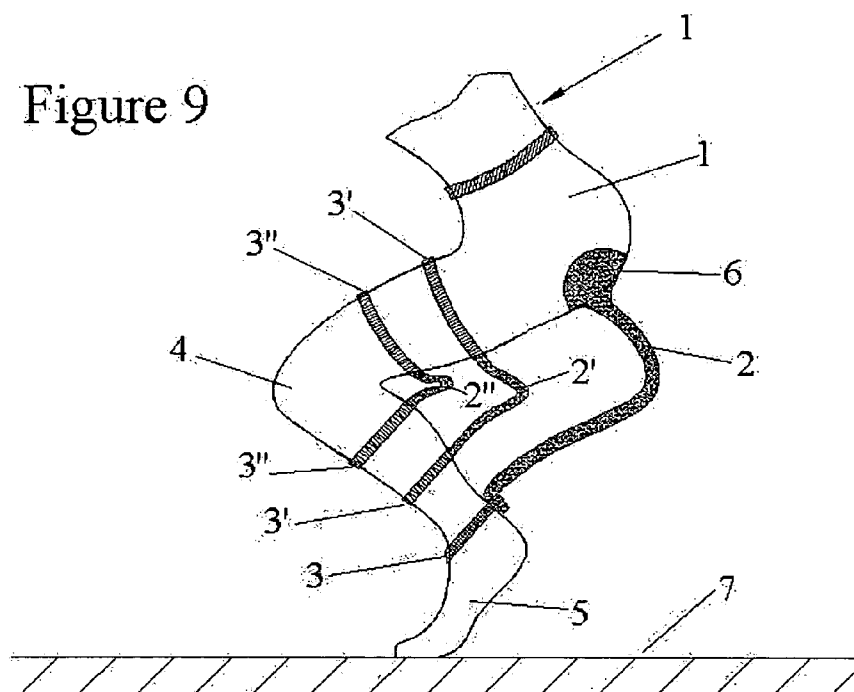


Figure 10

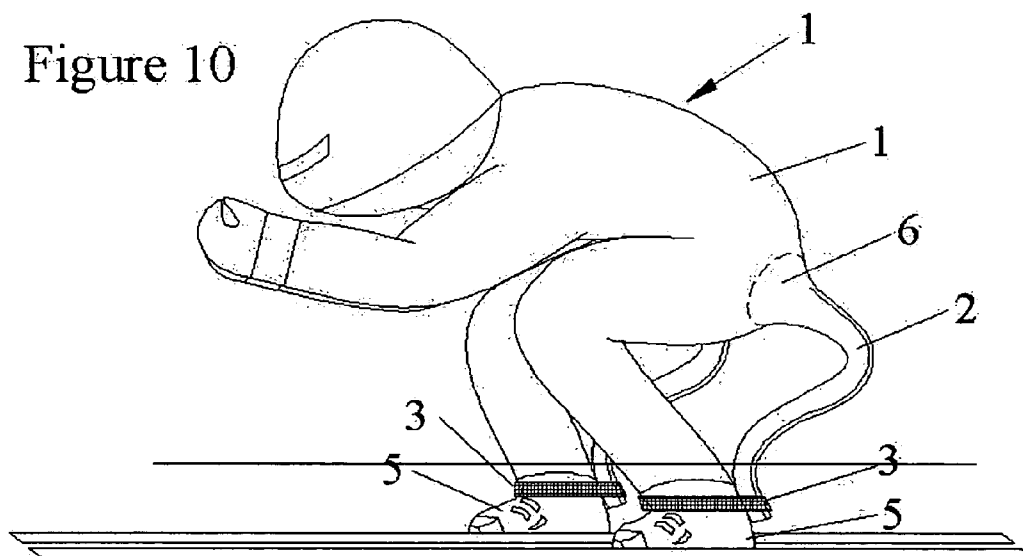


Figure 11

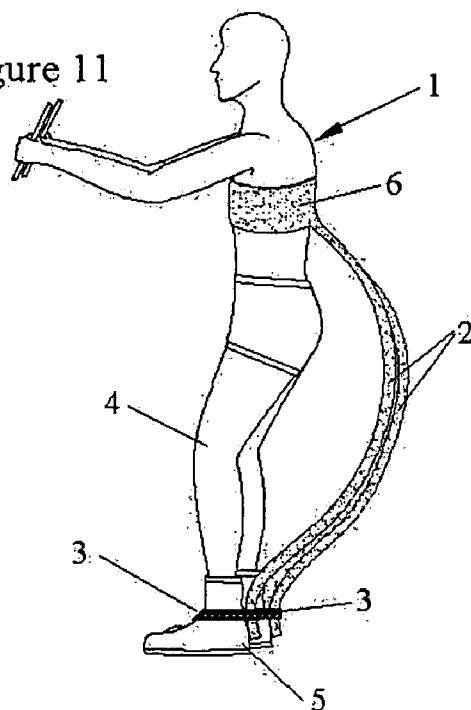


Figure 12

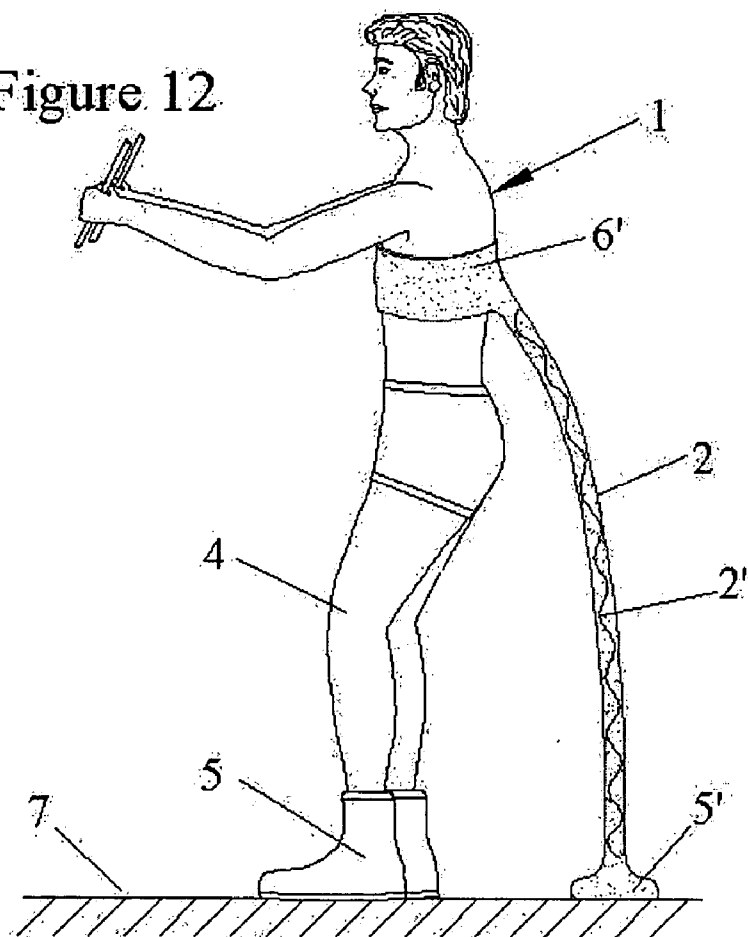
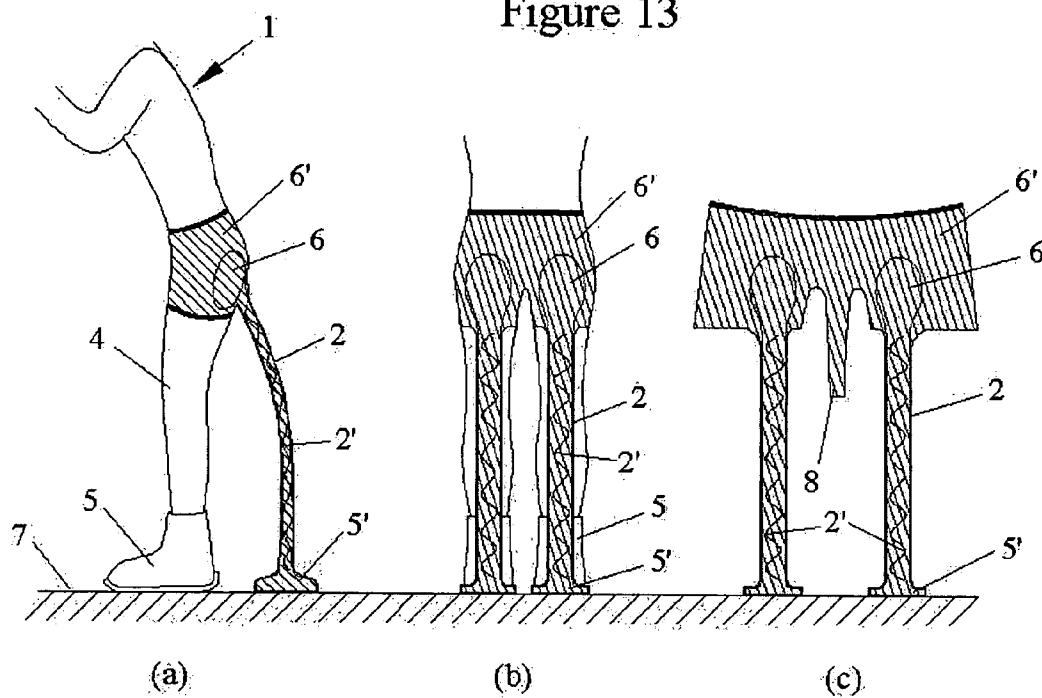


Figure 13



HUMAN LOWER LIMB PERFORMANCE ENHANCEMENT OUTFIT

BACKGROUND

[0001] The present invention relates to lower limb performance enhancement and augmentation outfits that can be worn by people to improve and enhance lower limb, as well as hip and waist, legs and knees performance in sports, daily dynamic activities and medical rehabilitation/physical therapy.

[0002] General everyday life activities, athletics and sports activities such as skiing and snowboarding and medical rehabilitation and physical therapy, exercise or training activities or the like excessively load the muscles of the leg (quadriceps, hamstrings and musculus gluteus maximus or the buttocks muscles), the bones of the leg such as femur, tibia and fibula and the knee anatomical parts such as the patella, quadriceps tendons and ligaments and often cause disorders in the lower limbs. Thus, a lower limb support and/or assist outfit having a structure for supporting the leg muscles and the knees has always been desirable and needed. The leg and knee support outfits must be biomimetic (mimicking biology or biological lower limbs), user-friendly and easily wearable by ordinary people to provide a comfortable fit without posing any danger to a user or having any medical restrictions. Furthermore, they should augment the power of the lower limbs by storing dynamic impact energy and using it to effectively reduce muscle fatigue and knee injury during such activities. Aside from medical and rehabilitation applications, lower limb and in particular legs and knees support and power augmentation have been extremely important in skiing. Skiers' legs are normally subject to a tremendous amount of strain and pressure. Even the professional downhill racers experience this strain and fatigue and are in search of ways to enhance their skiing performance. Furthermore, the older or less conditioned the skier, the greater the amount of stress and strain on their lower limbs.

[0003] Snowboarders also experience lower limb (leg and knee) strain and fatigue, which of course limits their jumping, turning and acrobatics. Accordingly, snowboarders as well as skiers have a dire need for a user-friendly outfit, which could enhance their performance by lessening the strain on their lower limbs.

[0004] There have been previous attempts to provide suitable supports. Willi in U.S. Pat. No. 4,021,053 entitled "Device providing improved support of the lower leg of a skier", issued May 3, 1977 teaches a support for the lower leg of a skier comprises an arm pivotally connected at one end to the upper part of the lower leg and at the other end to the ski through jaws gripping the ski-boot and firmly connected with the ski by the pressure of the boot sole thereon. Pivoting of the arm is controlled by a double acting resilient device, which is adjustable to vary the force on the arm and to vary the neutral position of the arm.

[0005] Willi in U.S. Pat. No. 4,265,462 entitled "Support device for skiers" issued May 5, 1981, teaches support devices for the shanks of skier's legs wherein levers on opposite sides of and parallel to the shank are pivoted about an axis at ankle height and secured to the shank just beneath the knee by a flexible strap. Two rods are pivoted to the lever arrangement on each side. In the case of a single lever the rods are pivoted above and below the lever axis. For parallel

levers one rod is pivoted above the axis of one lever and the other rod below the axis of the other lever. In each case the rods pass through a resilient compressible block. When the shank swings forward a stop on one rod compresses the block, while the other rod moves freely in the opposite direction. When the shank swings backward the roles of the rods are reversed.

[0006] Davis in U.S. Pat. No. 4,408,600 entitled "Leg aid device and method", issued Oct. 11, 1983, discusses a leg aid device and method for increasing the stamina of a body-supporting user's leg for repeated flexure and extension at the knee. The device comprises elongated flexibly resilient biasing means for placement in approximate alignment with a user's leg from a level near the ankle area up to at least the level of the mid-thigh area. The biasing means is adapted to bias a user's leg toward a straightened condition without significant torsion or twisting of the leg. Holding means maintains the biasing means approximately aligned upon a user's leg for bending yieldingly therewith into an overall actuate form during flexure of the leg at the knee. The biasing means, when held by the holding means upon a body-supporting user's leg, functions to support a portion of the user's body weight during times the biasing means is in bent condition with the user's leg in flexed condition, and functions to aid the user's leg muscles in causing extension of the user's leg from flexed condition as the biasing means resiliently returns toward a straightened condition with the extension of the user's leg.

[0007] A performance enhancement assembly is described in U.S. Pat. No. 4,759,570 to Walter Dandy, III, entitled "ski assembly" and issued Jul. 26, 1988. The Dandy assembly makes use of a rigid pole and spring assembly combination, which transfers the weight of the upper body of a skier from the skiers' legs to the skis during crouching movement of a skier. Dandy further refined his invention along with Tony Nespor in a series of patents.

[0008] Dandy, et al. in their U.S. Pat. No. 5,072,970 entitled "Performance enhancement assembly for skiers or the like" issued Dec. 17, 1991, teaches an apparatus for shifting the body weight of a skier from a skier's legs to the skis for enhancing the skier's performance and minimizing leg strain comprises a spring assembly including a loop of elastic rod-shaped material stretchable during crouching movement of a skier's legs between a standing position and a fully crouched position of the skier. A housing defining an elongated channel for enclosing a portion of the loop supports the stretchable material and parallel rod-shaped branches terminating in a base bend. The base bend is secured within one end of the housing. The housing also includes a socket for receiving rigid poles therein and supporting the poles in vertical positions above the skis. The top ends of the poles have pulleys therein over which a cord is fed extending from a top bend of the loop or elastic material to straps disposed about the thigh or thighs of the skier's legs. The housing is secured to the back of the boots of the skier so that the skier's weight transferred to the rigid poles is in turn transferred to the skis.

[0009] Dandy et al. in U.S. Pat. No. 5,131,684 entitled "Performance enhancement assembly for skiers or the like including ski pants", issued Jul. 21, 1992, presents an apparatus for shifting the body weight of a skier from a skier's legs to the skis for enhancing the skier's performance

and minimizing leg strain comprises a spring assembly including a loop of elastic rod-shaped material stretchable during crouching movement of a skier's legs between a standing position and a fully crouched position of the skier. A housing defining an elongated channel for enclosing a portion of the loop supports the stretchable material and parallel rod-shaped branches terminating in a base bend. The base bend is secured within one end of the housing. The housing also includes a socket for receiving rigid poles therein and supporting the poles in vertical positions above the skis. The top ends of the poles have pulleys therein over which a cord is fed extending from a top bend of the loop of elastic material through grommets located in a skier's pants to straps disposed about the thigh or thighs of the skier's legs. The housing is secured to the back of the boots of the skier so that the skier's weight transferred to the rigid poles is in turn transferred to the skis.

[0010] Dandy et al., in U.S. Pat. No. 5,131,685 entitled "Performance enhancement assembly for skiers or the like including ski poles with storage compartment", issued Jul. 21, 1992, teaches an apparatus for shifting the body weight of a skier from a skier's legs to the skis for enhancing the skier's performance and minimizing leg strain comprises a spring assembly including a loop of elastic rod-shaped material stretchable during crouching movement of a skier's legs between a standing position and a fully crouched position of the skier. A housing defining an elongated channel for enclosing a portion of the loop supports the stretchable material and parallel rod-shaped branches terminating in a base bend. The base bend is secured within one end of the housing. The housing also includes a socket for receiving rigid poles therein and supporting the poles in vertical positions above the skis. The top ends of the poles have pulleys therein over which a cord is fed extending from a top bend of the loop of elastic material to straps disposed about the thigh or thighs of the skier's legs. The housing is secured to the back of the boots of the skier so that the skier's weight transferred to the rigid poles is in turn transferred to the skis. Hollow tubular ski poles provide a convenient storage location for the rigid poles when not in use.

[0011] Dandy et al. in U.S. Pat. No. 5,161,825 entitled "Performance enhancement assembly for skiers or the like including swivel plate assembly" and issued Nov. 10, 1992, discloses an apparatus for shifting the body weight of a skier from a skier's legs to the skis for enhancing the skier's performance and minimizing leg strain comprises a spring assembly including a loop of elastic rod-shaped material stretchable during crouching movement of a skier's legs between a standing position and a fully crouched position of the skier. A housing defining an elongated channel for enclosing a portion of the loop supports the stretchable material and parallel rod-shaped branches terminating in a base bend. The base bend is secured within one end of the housing. The housing also includes a socket for receiving rigid poles therein and supporting the poles in vertical positions above the skis. The top ends of the poles have pulleys therein over which a cord is fed extending from a top bend of the loop of elastic material to straps disposed about the thigh or thighs of the skier's legs. The housing is pivotally secured to the back of the boots of the skier so that the skier's weight transferred to the rigid poles is in turn transferred to the skis.

[0012] Fuji et al. in the U.S. Pat. No. 6,186,970 entitled "Protective clothing for regions of lower limb", issued Feb. 13, 2001, presents a leg protection garment that is effective for mainly supporting the hamstrings, the muscle of the posterior side of the femoral region among the leg portion. The leg protection garment having a lower half of the body part which has a leg portion of length capable of covering at least the patella region and formed of stretchable fabric, the garment having a portion having a partially strong straining force, the portion having a strong straining force comprising at least a portion having a strong straining force **101** (A) which ranges from an area above the trochanter major to the vicinity **5** of the upper end of the tibia by way of the trochanter major and further the vicinity over the boundary between the musculus biceps femoris and the tractus ili-otibialis so as to support the musculus biceps femoris, wherein the portion obliquely crosses the vicinity **4** of the tendon region located below the muscle belly of the musculus biceps femoris without crossing the muscle belly of the musculus biceps femoris.

[0013] Many of the previous attempts involve hard mechanical parts, and have not been able to really address the problems with lower limb support and power augmentation. Fuji et al. is a garment that is effective for mainly supporting the hamstrings. Thus, there is a need for a user-friendly, soft and resilient, biomimetic (mimicking biological entities) lower limb, as well as hip and waist, support outfits that can be worn externally by people to improve and enhance lower limb, legs and knees performance in sports, daily dynamic activities and medical rehabilitation/physical therapy.

SUMMARY OF THE INVENTION

[0014] The present invention provides a user-friendly, soft and resilient, biomimetic (mimicking biological entities) lower limb, as well as hip and waist, support outfits that can be worn externally by people to improve and enhance lower limb, legs and knees performance in sports, daily dynamic activities and medical rehabilitation/physical therapy. The present invention provides an outfit, which allows a portion of the upper limb's quasi-static weight and dynamic weight due to impact forces to be excluded from being transmitted to the lower limb, hip and waist, legs, quadriceps and hamstrings muscles and knees by directly transmitting them to the ankles, footwear and/or the ground, through soft elastic columnar quasi-legs that are equipped with smart biomimetic materials such as shape memory materials and artificial muscles such as synthetic and/or ionic polymeric muscles and provide lower limb support function by buckling and bending in accordance with the maneuvering of the user. The said lower limb performance-enhancing outfit is encapsulated by user-friendly fabric means for easy wear. The upper portion of the outfit is in the form of a sports short worn by the user and encapsulating the buttocks support plates.

[0015] The present invention provides a system for enhancing the lower limb performance of an individual involved in sports or other dynamic activities involving the use of lower limbs, rehabilitating, involved in physical therapy and orthopedic recovery, running, jumping, turning, hopping, skiing or snowboarding which has a pair of biomimetic quasi-legs equipped with soft resilient elastic biomimetic smart materials such as shape memory materials

and artificial muscles such as synthetic and ionic polymeric muscles as disclosed in U.S. Pat. No. 6,109,852 to Shahinpoor, et al. entitled "Soft Actuators and Artificial Muscles", issued Aug. 29, 2000 and U.S. Pat. No. 6,475,639 to Shahinpoor, et al., entitled "Ionic Polymer Sensors and Actuators", issued Nov. 5, 2002.

[0016] The present invention can also provide a more user friendly and soft and elastic pair of biomimetic quasi-legs that are capable of biomimetically buckling and bending to maintain a controllable force and thus providing an additional smart and elastically compliant support in a lower limb and hip and waist performance enhancement outfit. The present invention can also provide a less cumbersome and more non-mechanical and biomimetic system, compared to the systems proposed in US patents described in the previous section for use in an individual's dynamic lower limb performance enhancement. The present invention can also provide a lower limb performance outfit that drastically differs from Dandy, et al., teachings in U.S. Pat. Nos. 5,161,825 and 5,131,685 and 5,131,684 and 5,072,970 by replacing the rigid rods and stretchable rubber loops and all other cumbersome mechanical parts by a simple pair of compliant biomimetic bending rather than stretching legs to enhance the lower limb performance.

[0017] The present invention can provide soft, compliant, biomimetic and unique coupling and enhancement means arching between the upper limb through musculus gluteus maximus (the buttocks muscles) and the lower limb, as well as hip and waist, of an individual involved in dynamic activities involving the use of lower limb and placing dynamic loads on the lower limb muscles and the knees. The present invention can provide a unique performance enhancement outfit which is worn by the user in a comfortable fashion, and with an aesthetically pleasing appearance. The present invention can comprise lower limb assist and/or support outfits that can be worn by people to improve and enhance lower limb, as well as hip and waist, legs and knees performance in sports, daily dynamic activities and medical rehabilitation/physical therapy, which allows a portion of the upper limb's quasi-static weight and dynamic weight due to impact forces to be excluded from being transmitted to the lower limb, as well as hip and waist, legs, quadriceps and hamstrings muscles and knees by directly transmitting them to the ankles, footwear and/or the ground, through soft elastic columnar quasi-legs that are equipped with biomimetic smart materials and artificial muscles and provide lower limb support function by columnar buckling and bending in accordance with the dynamics movement and maneuvering of the user.

[0018] The present invention can provide a one piece, user-friendly non-cumbersome means, biomimetic, compliant, bendable pair of quasi-legs to enhance lower limb performance in dynamic activities. The present invention can provide a one piece outfit wearable in a user-friendly manner with bendable biomimetic quasi-legs equipped with biomimetic smart materials and artificial muscles to enhance lower limb performance in dynamic activities. The present invention can be very simple and inexpensive to manufacture.

DESCRIPTION OF THE FIGURES

[0019] The invention is explained by using embodiment examples and corresponding drawings, which are incorporated into and form part of the specification.

[0020] FIG. 1 is a side view of an individual wearing the lower limb performance enhancement outfit of the present invention in an upright position.

[0021] FIG. 2 is a side view of an individual wearing the lower limb performance enhancement outfit of the present invention in a tuck position with bent knees.

[0022] FIG. 3 is a back view of an individual wearing the lower limb performance enhancement outfit of the present invention in either an upright or a tuck position.

[0023] FIG. 4 is a comparative side view of an individual wearing the lower limb performance enhancement outfit of the present invention in two consecutive positions of upright and tuck or bent.

[0024] FIG. 5 is three-dimensional view of the biomimetic quasi-leg with buttocks support plate equipped with smart materials and/or artificial muscles in an initial upright position.

[0025] FIG. 6 is three-dimensional view of the biomimetic quasi-leg with buttocks support plate equipped with smart materials and/or artificial muscles in a buckled/bent position.

[0026] FIG. 7 is three-dimensional view of the pair of biomimetic quasi-legs with buttocks support plates equipped with smart materials and/or artificial muscles in an initial upright position.

[0027] FIG. 8 is three-dimensional view of the pair of biomimetic quasi-legs with buttocks support plates equipped with smart materials and/or artificial muscles in a buckled/bent position.

[0028] FIG. 9 is a side view of an individual wearing multiple lower limb performance enhancement outfits of the present invention in a tuck position with bent knees.

[0029] FIG. 10 is a side view of a skier wearing the lower limb performance enhancement outfit of the present invention in a tuck position with bent knees.

[0030] FIG. 11 is an illustration of another embodiment of the present invention in which the lower limb and hip and waist performance enhancing outfit is worn like a under arm support vest on the torso of an individual with under arms support in an upright.

[0031] FIG. 12 is an illustration of another embodiment of the present invention in which the lower limb and hip and waist performance enhancing outfit is worn like a under arm support vest on the torso of an individual with under arms support in an upright position with the bottom of the quasi legs on the ground.

[0032] FIG. 13 is an illustration of another embodiment of the present invention in which the lower limb and hip and waist performance enhancing outfit is worn like an outfit supported between the buttocks plates and bottom plates on the ground.

DETAILED DESCRIPTION

[0033] The present invention provides a user-friendly, soft and resilient, biomimetic (mimicking biological entities) lower limb, as well as hip and waist, support outfits that can be worn externally by people to improve and enhance lower limb, legs and knees performance in sports, daily dynamic

activities and medical rehabilitation/physical therapy. The present invention provides an outfit, which allows a portion of the upper limb's quasi-static weight and dynamic weight due to impact forces to be excluded from being transmitted to the lower limb, hip and waist, legs, quadriceps and hamstrings muscles and knees by directly transmitting them to the ankles, footwear and/or the ground, through soft elastic columnar quasi-legs that are equipped with smart biomimetic materials such as shape memory materials and artificial muscles such as synthetic and/or ionic polymeric muscles and provide lower limb support function by buckling and bending in accordance with the maneuvering of the user. The said lower limb performance-enhancing outfit is encapsulated by user-friendly fabric means for easy wear. The upper portion of the outfit is in the form of a sports short worn by the user and encapsulating the buttocks support plates.

[0034] The present invention provides a system for enhancing the lower limb performance of an individual involved in sports or other dynamic activities involving the use of lower limbs, rehabilitating, involved in physical therapy and orthopedic recovery, running, jumping, turning, hopping, skiing or snowboarding which has a pair of biomimetic quasi-legs equipped with soft resilient elastic biomimetic smart materials such as shape memory materials and artificial muscles such as synthetic and ionic polymeric muscles as disclosed in U.S. Pat. No. 6,109,852 to Shahinpoor, et al. entitled "Soft Actuators and Artificial Muscles", issued Aug. 29, 2000 and U.S. Pat. No. 6,475,639 to Shahinpoor, et al., entitled "Ionic Polymer Sensors and Actuators", issued Nov. 5, 2002.

[0035] The present invention can also provide a more user friendly and soft and elastic pair of biomimetic quasi-legs that are capable of biomimetically buckling and bending to maintain a controllable force and thus providing an additional smart and elastically compliant support in a lower limb and hip and waist performance enhancement outfit. The present invention can also provide a less cumbersome and more non-mechanical and biomimetic system, compared to the systems proposed in US patents described in the previous section for use in an individual's dynamic lower limb performance enhancement. The present invention can also provide a lower limb performance outfit that drastically differs from Dandy, et al. teachings in U.S. Pat. Nos. 5,161,825 and 5,131,685 and 5,131,684 and 5,072,970 by replacing the rigid rods an stretchable rubber loops and all other cumbersome mechanical parts by a simple pair of compliant biomimetic bending rather than stretching legs to enhance the lower limb performance.

[0036] The present invention can provide soft, compliant, biomimetic and unique coupling and enhancement means arching between the upper limb through musculus gluteus maximus (the buttocks muscles) and the lower limb, as well as hip and waist, of an individual involved in dynamic activities involving the use of lower limb and placing dynamic loads on the lower limb muscles and the knees. The present invention can provide a unique performance enhancement outfit which is worn by the user in a comfortable fashion, and with an aesthetically pleasing appearance. The present invention can comprise lower limb assist and/or support outfits that can be worn by people to improve and enhance lower limb, as well as hip and waist, legs and knees performance in sports, daily dynamic activities and medical

rehabilitation/physical therapy, which allows a portion of the upper limb's quasi-static weight and dynamic weight due to impact forces to be excluded from being transmitted to the lower limb, as well as hip and waist, legs, quadriceps and hamstrings muscles and knees by directly transmitting them to the ankles, footwear and/or the ground, through soft elastic columnar quasi-legs that are equipped with biomimetic smart materials and artificial muscles and provide lower limb support function by columnar buckling and bending in accordance with the dynamics movement and maneuvering of the user.

[0037] The present invention can provide a one piece, user-friendly non-cumbersome means, biomimetic, compliant, bendable pair of quasi-legs to enhance lower limb performance in dynamic activities. The present invention can provide a one piece outfit wearable in a user-friendly manner with bendable biomimetic quasi-legs equipped with biomimetic smart materials and artificial muscles to enhance lower limb performance in dynamic activities. The present invention can be very simple and inexpensive to manufacture.

[0038] Referring to FIG. 1, note that the individual 1' is in a standing upright position in a dynamic activities setting while wearing the lower limb performance enhancing outfit 1, whose upper portion is a short to be worn by an individual with embedded buttocks support plates 6 with its quasi-legs 2 behind the lower limb 4 and footwear straps 3 securely attaching the lower part of the quasi-legs part of the outfit to footwear 5 on the ground 6. The lower limb performance enhancement outfit of the present invention operates such that when there is dynamic activities or impact or other means causing or forcing the lower limb to bend such as shown in FIG. 2, the quasi-legs 2 buckle and bend between the embedded buttocks support plates 6 and securely tightened straps 3 and footwear 5 to transfer part of the dynamic force or upper body weight directly to the footwear 5 and subsequently to the ground 6. Note that because of the aspect ratio of the quasi-legs, the bending/flexing is only on the plane of the legs, namely, backward from the human body, as shown in FIG. 1, rather than sideways from the human body. In fact, considering the Euler's critical buckling load (see J. E. Shigley, and R. Mischke, *Mechanical Engineering Design*, 5th ed., McGraw-Hill Co, New York 1989), namely:

$$P_{cr} \approx \frac{\pi^2 EI}{l_{eff}^2} \quad (1)$$

[0039] where E is the Young's modulus of elasticity of the quasi-legs 2, I is its moment of inertia in the plane of bending and l_{eff} is its effective length from the point of attachment to the buttocks support plates 6 to the point of attachment of the straps 3 to the footwear 5. If the end conditions of the quasi-legs are clamped-clamped, then $l_{eff}=0.65 I$, where I is the actual length between the point of attachment of quasi-legs to the buttocks support plates 6 and the point of attachment of the straps 3 to the footwear 5. Thus, if the width of the quasi-legs is w and its thickness is t, the moment of inertia for bending is:

$$I = wt^3/12 \quad (2)$$

[0040] Taking, for example, w=6 cm, t=2 cm, the $I=[6 \times 8/12]=4 \text{ cm}^4$. Assuming the quasi-leg material to be, say,

porous rubber-like material like porous Neoprene of length $L=1$ m, then the Young's modulus of Elasticity E is about 0.1 GPa and thus the critical buckling load will be:

$$P_{cr} = \frac{\pi^2 \times 10^8 \text{ N/m}^2 \times 4 \times 10^{-8} \text{ m}^4}{(0.65)^2} = 93.345 \text{ N} = 9.525 \text{ Kg} = 21 \text{ Lbs.} \quad (3)$$

[0041] This will be the initial load taken and shifted to the ground by each quasi-leg for a total load carrying of almost 42 Lbs by the pair of quasi-legs, which is quite significant for enhancing the performance of lower limbs.

[0042] Referring to FIG. 3 which depicts the outfit from the back side of the user, note again that the individual 1' is in a standing upright position in a dynamic activities setting while wearing the lower limb performance enhancing outfit 1, whose upper portion is a short to be worn by an individual with embedded buttocks support plates 6 with its quasi-legs 2 behind the lower limb 4 and footwear straps 3 securely attaching the lower part of the quasi-legs part of the outfit to footwear 5 on the ground 6. The lower limb performance enhancement outfit of the present invention operates such that when there is dynamic activities or impact or other means causing or forcing the lower limb to bend such as shown in FIG. 2, the quasi-legs 2 buckle and bend between the embedded buttocks support plates 6 and securely tightened straps 3 and footwear 5 to transfer part of the dynamic force or upper body weight directly to the footwear 5 and subsequently to the ground 6. Note that because of the aspect ratio of the quasi-legs, the bending/flexing is only in the plane of the legs and knees, namely, backward from the human body, as shown in FIGS. 1 and 2 rather than sideways from the human body.

[0043] FIG. 4 depicts the outfits in a user in both the upright and the bent positions for comparison. This is a comparative side view of an individual wearing the lower limb performance enhancement outfit of the present invention in two consecutive positions of upright and tuck. Note again that the individual 1' is in both a standing upright position, as well as in a tuck position, in a dynamic activities setting while wearing the lower limb performance enhancing outfit 1, whose upper portion is a short to be worn by an individual with embedded buttocks support plates 6 with its quasi-legs 2 behind the lower limb 4 and footwear straps 3 securely attaching the lower part of the quasi-legs part of the outfit to footwear 5 on the ground 6. The lower limb performance enhancement outfit of the present invention operates such that when there is dynamic activities or impact or other means causing or forcing the lower limb to bend such as shown in FIG. 2, The quasi-legs 2 buckle and bend between the embedded buttocks support plates 6 and securely tightened straps 3 and footwear 5 to transfer part of the dynamic force or upper body weight directly to the footwear 5 and subsequently to the ground 6. Note that because of the aspect ratio of the quasi-legs, the bending/flexing is only in the plane of the legs and knees, namely, backward from the human body, as shown in FIGS. 1 and 2 rather than sideways from the human body.

[0044] FIG. 5 is a three-dimensional view of a single biomimetic quasi-leg 2 with buttocks support plate 6 and binding straps 3 equipped with embedded smart materials and/or artificial muscles 9 in an initial upright position. These quasi-legs can be manufactured in one piece by molding techniques such as injection molding, compression molding, thermoforming, urethane casting, and dip molding,

and then may be encapsulated in a user friendly fabric and be embedded in a tight, short or underarm support vest to be worn by the user.

[0045] FIG. 6 is a three-dimensional view of a single biomimetic quasi-leg 2 with buttocks support plate 6 and binding straps 3 equipped with embedded smart materials and/or artificial muscles 9 in a buckled/bent position.

[0046] FIG. 7 is a three-dimensional view of a pair of biomimetic quasi-legs 2 with buttocks support plate 6 and binding straps 3 equipped with embedded smart materials and/or artificial muscles 9 in an initial upright position.

[0047] FIG. 8 is a three-dimensional view of a pair of biomimetic quasi-legs 2 with buttocks support plate 6 and binding straps 3 equipped with embedded smart materials and/or artificial muscles 9 in a buckled/bent position.

[0048] FIG. 9 is a side view of an individual 1 involved in sports, daily dynamic activities and medical rehabilitation/physical therapy wearing multiple lower limb performance enhancement outfits of the present invention in a tuck position with bent knees on support platform or ground 7. Here the quasi legs 2 with buttocks support plate 6 embedded in the wearable short 1 and supported between the support plates 6 and footwear 5 by binding straps 3 and quasi legs 2' and 2'' with upper and lower leg support straps 3' and 3''.

[0049] FIG. 10 is a side view of a skier 1 wearing the lower limb performance enhancement outfit 1 of the present invention in a tuck position with bent knees. Here again the quasi legs 2 are supported between the buttocks support plates 6 embedded in ski outfit 1 and the binding straps 3 attached to footwear 5. All dynamic impacts imparted to the lower limb of the skier are partially transmitted to the ski boots 5 and excluded from the lower limb muscles and knee of the skier, thus enhancing the skiers' performance.

[0050] FIG. 11 shows another embodiment of the present invention worn by a user 1 involved in sports, daily dynamic activities and medical rehabilitation/physical therapy. Note that the lower limb and hip and waist performance enhancing outfit 6' is worn like an under arm support vest on the torso of an individual with under arms support to act like a pair of biomimetic crouches or quasi legs 2 supported between the under arm support vest 6' and the binding straps 3 attached to the footwear 5 in an upright position.

[0051] FIG. 12 shows another embodiment of the present invention worn by a user 1 involved in daily dynamic activities requiring a person to stand for long hours like flight attendants and the like, and medical rehabilitation/physical therapy. Note that the lower limb and hip and waist performance enhancing outfit 6' is worn like an under arm support vest on the torso of an individual with under arms support to act like a pair of biomimetic crouches or quasi legs 2 supported between the under arm support vest 6' and the bottom support plates 5' on the ground 7. in an upright position.

[0052] FIG. 13 shows another embodiment of the present invention worn by a user 1 involved in daily dynamic activities requiring a person to stand for long hours like flight attendants and the like, and medical rehabilitation/physical therapy. Note that the lower limb and hip and waist performance enhancing outfit 6' is worn on the hip with

buttocks support plates 6 with the quasi legs 2 serve like a pair of biomimetic crouches or quasi legs 2 supported between the buttocks support plates 6 and the bottom support plates 5' on the ground 7 in an upright position.

[0053] The present invention can comprise various embodiments. Some examples include:

[0054] A wearable outfit for enhancing the performance of human lower limb, as well as hip and waist, by transferring a portion of the static and dynamic weight or impact load imparted to an individual to his or her footwear, thus partially bypassing the individual's lower limb, the outfit comprising a short, a single biomimetic quasi-leg or a pair of biomimetic quasi-legs with embedded buttocks support plates, resilient buckling/bending column embedded with elastic, resilient smart materials and artificial muscles, and footwear binding strap means disposable about the ankle or the footwear of an individual. The outfit can also comprise synthetic rubbers such as Neoprene or polychloroprene embedded in the quasi-legs and buttocks support plates. The outfit can also comprise natural rubbers such as Latex or polymer of isoprene from rubber tree (*Hevea brasiliensis*) embedded in the quasi-legs and buttocks support plates. The outfit can also comprise smart materials such as shape memory materials embedded in the quasi-legs and buttocks support plates. The outfit can also comprise artificial muscles such as synthetic muscles and ionic polymeric muscles embedded in the quasi-legs and buttocks support plates.

[0055] An outfit for dynamic activities of the human body in sports, every day activities, medical rehabilitation and physical therapy and the like to lessen the effect of the body static and dynamic weights and dynamic impacts to the lower limb, as well as hip and waist, of an individual by transferring part of such body static and dynamic weights and dynamic impacts from the upper body to the ankle or footwear of an individual.

[0056] Any of the examples can comprise multiple biomimetic quasi-legs or a pairs of biomimetic quasi-legs with embedded buttocks support plates, binding straps, resilient buckling/bending columns embedded with elastic, resilient smart materials and artificial muscles, and footwear binding strap means disposable about the ankle or the footwear of an individual.

[0057] Any of the examples can be applied to a skier for enhancing the performance of the skiers' lower limb, by transferring a portion of the static and dynamic weight or impact load imparted to the skier to his or her ski boots, thus partially bypassing the skiers' lower limb.

[0058] Any of the examples can comprise an under arm support vest, a single biomimetic quasi-leg or a pair of biomimetic quasi-legs with embedded under arm support vest, resilient buckling/bending column embedded with elastic, resilient smart materials and artificial muscles, and footwear binding strap means disposable about the ankle or the footwear of an individual.

[0059] Any of the examples can be worn on the torso of an individual for enhancing dynamic activities in sports, every day activities, medical rehabilitation and physical therapy and the like to lessen the effect of the body static and dynamic weights and dynamic impacts to the lower limb, as well as hip and waist, of an individual by transferring part

of such body static and dynamic weights and dynamic impacts from the upper body to the ankle or footwear of an individual, and comprise an under arm support vest, a single biomimetic quasi-leg or a pair of biomimetic quasi-legs with embedded under arm support vest, resilient buckling/bending column embedded with elastic, resilient smart materials and artificial muscles, and footwear binding strap means disposable about the ankle or the footwear of an individual.

[0060] Any of the examples can be worn like an under arm support vest on the torso of an individual with under arms support to act like a pair of biomimetic crouches or quasi legs supported between the under arm support vest and the bottom support plates on the ground, in an upright position with quasi-legs supported on the ground a user stands and walks on to be worn by the user involved in daily dynamic activities requiring a person to stand for long hours like flight attendants and the like.

[0061] Any of the examples can be worn like short on the waist and hip of an individual with buttock's support plates to act like a pair of biomimetic quasi legs supported between the buttocks support plates the bottom support plates on the ground, in an upright position with quasi-legs supported on the ground a user stands and walks on to be worn by the user involved in daily dynamic activities requiring a person to stand for long hours like flight attendants and the like.

[0062] The particular sizes and equipment discussed above are cited merely to illustrate particular embodiments of the invention. It is contemplated that the use of the invention may involve components having different sizes and characteristics. It is intended that the scope of the invention be defined by the claims appended hereto.

1) A human performance enhancement apparatus, comprising a biomimetic quasi-leg, having first and second ends and extending along a path therebetween, wherein the quasi-leg is bendable along a direction transverse to the path, wherein the first end: comprises a structure that mounts with an ankle or foot of a human, which mounting provides a firm attachment with the ankle or foot both when the ankle or foot is at rest and when the ankle or foot is in motion, and wherein the second end comprises a structure that mounts with the buttocks of a human, which mounting provides load transference from the buttocks to the structure both when the human is at rest and when the human is in motion.

2) An apparatus as in claim 1, wherein the first end comprises a binding strap suitable for attachment to a human ankle or to a human foot.

3) An apparatus as in claim 1, wherein the first end comprises footwear suitable for wear by a human.

4) An apparatus as in claim 1, wherein the second end comprises a buttocks support plate.

5) An apparatus as in claim 1, wherein the quasi-leg comprises a resilient column.

6) An apparatus as in claim 5, wherein the resilient column comprises a shape memory alloy.

7) An apparatus as in claim 5, wherein the resilient column comprises a synthetic polymeric muscle, an ionic polymeric muscle, or a combination thereof.

8) An apparatus as in claim 1, further comprising fabric encapsulating at least a portion of the apparatus.

9) An apparatus as in claim 1, further comprising a second biomimetic quasi-leg, having first and second ends, and extending along a path therebetween, wherein the second

quasi-leg is bendable along a direction transverse to the path, wherein the first end comprises a structure that mounts with an ankle or foot of a human, which mounting provides a firm attachment with the ankle or foot both when the ankle or foot is at rest and when the ankle or foot is in motion, and wherein the second end comprises a structure that mounts with the buttocks of a human, which mounting provides load transference from the buttocks to the structure both when the human is at rest and when the human is in motion.

10) A human performance enhancement apparatus, comprising a biomimetic quasi-leg, having first and second ends, and extending along an path therebetween, wherein the quasi-leg is bendable along a direction transverse to the path, wherein the second end comprises a second structure that mounts with a portion of the human body above the knee, which mounting provides a firm attachment of the second structure to the portion of the human body both when the body is at rest and when the body is in motion, and wherein the first end comprises a first structure that mounts with a portion of the human body below the knee, which mounting provides a firm attachment of the first structure to the portion of the human body both when the body is at rest and when the body is in motion.

11) An apparatus as in claim 10, wherein the first structure provides a firm attachment with a human foot or ankle.

12) An apparatus as in claim 11, wherein the second structure provides a firm attachment with a human waist.

13) An apparatus as in claim 11, wherein the second end structure provides a firm attachment with a human torso.

14) An apparatus as in claim 11, further comprising a second biomimetic quasi-leg, having first and second ends, and extending along an path therebetween, wherein the second quasi-leg is bendable along a direction transverse to the path, wherein the second end comprises a second structure that mounts with a portion of the human body above the knee, which mounting provides a firm attachment of the second structure to the portion of the human body both when

the body is at rest and when the body is in motion, and wherein the first end comprises a first structure that mounts with a portion of the human body below the knee, which mounting provides a firm attachment of the first structure to the portion of the human body both when the body is at rest and when the body is in motion.

15) A human performance enhancement apparatus, comprising a biomimetic quasi-leg, having first and second ends, and extending along an path therebetween, wherein the second quasi-leg is bendable along a direction transverse to the path, wherein the second end comprises a second structure that mounts with a portion of the human body above the knee, which mounting provides a firm attachment of the second structure to the portion of the human body both when the body is at rest and when the body is in motion, and wherein the first end comprises a first structure that mounts in a substantially fixed relationship with a portion of the human body below the knee, which mounting provides a firm attachment of the first structure to the portion of the human body both when the body is at rest and when the body is in motion.

16) An apparatus as in claim 15, wherein the first structure provides for mounting with a ski boot, ski binding, or ski.

17) An apparatus as in claim 15, wherein the second structure comprises a vest.

18) An apparatus as in claim 15, wherein the first structure comprises a foot mountable with a floor or support stand on which a user of the apparatus stands.

19) An apparatus as in claim 10, wherein the biomimetic quasi-leg comprises a bendable resilient column.

20) An apparatus as in claim 19, wherein the column comprises a material chosen from the group consisting of (a) synthetic polymeric artificial muscle, and (b) ionic polymeric artificial muscle.

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