Title: Body image distortions following spinal cord injury

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ABSTRACT

Background: Following spinal cord injury (SCI) or anaesthesia, people may continue to experience feelings of the size, shape, and posture of their body, suggesting that the conscious body image is not fully determined by immediate sensory signals. How this body image is affected by changes in sensory inputs from, and motor outputs to the body remains unclear.

Methods: We tested paraplegic and tetraplegic SCI patients on a task that yields quantitative measures of body image. Participants were presented with an anchoring stimulus on a computer screen and told to imagine that the displayed body part was part of a standing mirror image of themselves. They then identified the position on the screen, relative to the anchor, where each of several parts of their body would be located. Veridical body dimensions were identified based on measurements and photographs of participants.

Results: Compared to age-matched controls, paraplegic and tetraplegic patients alike perceived their torso and limbs as elongated relative to their body width. No effects of lesion level were found.

Conclusions: The common distortions in body image across patient groups, despite differing SCI levels, imply that a body image may be maintained despite chronic sensory and motor loss. Systematic alterations in body image follow SCI, though our results suggest these may reflect prolonged changes in body posture and wheelchair use, rather than loss of specific sensorimotor pathways. These findings provide new insight into how the body image is maintained, and may prove useful in treatments that intervene to manipulate the body image.

KEY WORDS:

spinal cord injury, body image, body representations, sensory loss, rehabilitation

INTRODUCTION

In order to interpret sensory information and interact with our environment, the brain requires a model of the body that represents body part size, shape, and configuration. This representation of the body can be thought of as a conscious “body image” and reflects what the body is perceived to be like[1]. Note that use of this term in the scientific literature need not include the emotional and aesthetic elements associated with it in everyday use, and in some psychological traditions[2]. It remains unclear how sensory and motor information contribute to our conscious body image.

Studying the effects of sensory loss on body representations can reveal the role played by afferent information in the body image. Following damage to the spinal cord or anesthesia, affected body parts are not perceived as having vanished. Rather, vivid ‘phantom’ experiences can be maintained[3-6]. In paraplegia, patients commonly report feelings that their body feels larger than actual size[3-5]. Similar results have been found following acute deafferentation: anaesthetising digits in healthy adults results in increased perceived size of the digit[7;8]. On the other hand, the perception of phantom limbs (i.e., the presence of the missing limb) after traumatic amputation often results in shrinkage and telescoping of the perceived limb[9;10]. Studying patients with spinal cord injuries may help clarify these conflicting findings.

Spinal cord injury (SCI) patients present loss of motor and sensory functions below the level of injury, with the extent of loss depending on the degree of tissue damage. SCI patients therefore provide important insight into the effects of sensorimotor loss on one’s body image. Moreover, functional and structural cortical reorganisation following SCI[11-15] provide a method to investigate the relation between neural plasticity and conscious body image.

Almost five decades ago, a study demonstrated that paraplegic patients overestimate their shoulder width[16]. Conomy[4] continued the study of body image in SCI a decade later by qualitatively assessing disturbances in patients. In addition to disturbances in limb position, posture, and movement, seven of the 18 SCI patients, including tetraplegic (cervical lesion) and paraplegic (thoracic lesions) patients, reported changes in body component size, specifically increased foot and leg size. These assessments, however, were not quantified, and it is unclear whether the disorders were directly due to sensorimotor loss, or to some secondary factor such as immobilisation. A later study indicated only slight differences in body size estimates between individuals with acquired (SCI) and congenital (cerebral palsy) motor impairments[17].

A more thorough assessment of body image in SCI patients could provide insight into how the body image depends on sensorimotor information, and what distortions may result from an absence of afferent signals. Moreover, assessing the body image following SCI can provide insight into the brain areas that are involved in forming and maintaining the body image. Here we apply a new quantitative test of body image in wheelchair-bound paraplegic and tetraplegic patients to establish what distortions are present, and how they relate to the level of injury.

METHODS

Participants

Forty-two participants took part in the study: 12 paraplegic patients (PPP, 1 female, 39.8±11.0 years), 12 tetraplegic patients (TPP, 1 female, 36.3±13.1 years), and 18 healthy controls (CTL, 1 female, 42.5±11.1 years). The three groups did not differ in age or level of education. Table 1 contains clinical information for the patient groups. Informed written consent was obtained for all procedures, and the study was approved by the ethics committee of Santa Lucia Hospital, Rome.

For SCI patients, the neurological injury level was determined using the American Spinal Injury Association (ASIA) standards for classification of SCI[18]. Each patient was examined by an expert neurologist (G.S.), and a standardized ASIA protocol was used to determine the most caudal level of the spinal cord with normal sensory and motor function on both sides of the body (Table 1). All patients were manual wheelchair users and were recruited from physiotherapy programs for patients with SCI. No patient had suffered a head or brain lesion.

Body Image Task (BIT)

Procedure

The task was based on a concept developed by Daurat-Hmeljiak et al.[19], with a number of extensions. Participants were seated in front of a table with a 10.4 inch touch-screen monitor. A researcher explained that during the task they would see either the outline of a head near the top of the screen or the outline of a left or right foot near the bottom of the screen ("anchors", see Figure 1). Participants were instructed to imagine that they were looking at a mirror image of themselves standing with their arms at their sides; a researcher briefly demonstrated this position to each participant. Participants were told to scale the imagined picture of themselves such that the size of their head or the size of their foot matched the size of the displayed anchor on the screen. The name of a body part to be placed on that trial was displayed on the screen for three seconds, after which one of the anchor stimuli was displayed at one of four random positions on the screen (one of four positions near the top of the screen for the head anchor and one of four positions near the bottom for the foot anchors, Figure 1). Participants used a stylus to tap the screen where they thought the named body part would be located on their image of their own body in the canonical position, relative to the displayed anchor. Participants were given four seconds to respond before the next trial began.

Participants identified the location of 14 body parts (13 per anchor): head (for right and left foot anchor blocks), left shoulder, right shoulder, left elbow, right elbow, left hand, right hand, left hip, right hip, navel, left knee, right knee, left foot (for head and right foot anchor blocks), and right foot (for head and left foot anchor blocks). Trials were blocked by anchor. There were two blocks for each of the three anchors. The first three blocks were presented in a random order, and the subsequent three were given in the mirror order. Each body part was repeated four times per block in a pseudo-random order, for a total of eight trials per body part, per anchor.

A researcher identified the 14 body parts that were to be tested during the task by pointing to their location on herself during the initial demonstration of the test position. Participants completed a three-trial practice with the head anchor and a three-trial practice with the right-foot anchor before starting the experiment.

Analysis

We calculated the average reported position of each body part, for each anchor. Responses that clearly confounded the left and right sides of the body or were beyond two standard deviations of the participant's mean were excluded from analysis. On average, 5% of trials per participant were excluded.

For our first analysis we compared all body part lengths across groups. Average reported body part positions were transformed into a common space by expressing them as a proportion of judged height (y-distance from head to feet)[20]. This allowed for comparisons of the relative lengths of different body parts across anchors and participants. Examples of the body image based on this common space are shown in Figure 3. The following body part lengths were then calculated:

- Head to left and right shoulder
- Head to navel
- Shoulder width (left shoulder to right shoulder)
- Upper arm length (shoulder to elbow), left and right
- Lower arm length (elbow to hand), left and right
- Total arm length (shoulder to hand), left and right
- Torso length (shoulder to hip), left and right
- Navel to hip, left and right
- Hip width (left hip to right hip)
- Upper leg length (hip to knee), left and right
- Lower leg length (knee to foot), left and right
- Total leg length (hip to foot), left and right

All lengths were then expressed as the difference between the perceived length and the participant's true body part length, as a proportion of the true length. We performed a repeated measures ANOVA with body parts (21) and anchor (3) as within group factors and group (3) as a between group factor.

In a second analysis we compared body aspect ratios. We calculated the following three ratios for each participant, for each anchor: torso length/hip width, arm length/shoulder width, and leg length/hip width. Ratios were then expressed as the difference between the perceived ratio and the participant's true ratio, as a proportion of the true ratio. Thus, ratios of zero represent accurate perception of true body aspect. Ratios greater than zero represent perceived elongation of either the torso, arms, or legs relative to perceived body width, while ratios less than zero represent perceived shortening of the torso, arms, or legs relative to perceived body width. We performed a repeated measures ANOVA with these body aspect ratios (3) and anchor (3) as within group factors and group (3) as a between group factor.

Template Selection Task

Procedure

In this task, participants identified which of a range of visually-presented body shapes corresponded most closely to the perceived shape of their own body. Based on the true dimensions of 18 control participants (not included in this dataset), a figure with a hip width/height ratio of 0.177 was created, with a dot marking the location of each body part identified in the BIT. The width of the figure was altered to create 13 templates with widths ranging from 40% to 160% of the original, average width, in increments of 10%.

After completion of the BIT, participants performed the template selection task, based on these width altered templates. On each trial, nine of these figures were placed side-by-side in order of increasing width (Figure 2). Participants were instructed to select the figure they felt most closely matched their body shape. There were a total of nine trials, each with a different starting figure, and trials were presented in a random order.

Analysis

For each participant, the hip width/height ratio of each template selected was averaged across the nine trials. This averaged template ratio was compared to the participant's true hip width/height ratio. Differences between true ratios and average selected template ratios were compared across groups.

Participant's True Body Dimensions

We took the following measurements from each participant, in order to compare the perceived positions of body parts with their actual positions relative to each other:

- Left shoulder to right shoulder

- Right shoulder to right elbow
- Right elbow to centre of palm of right hand
- Right shoulder to right pelvic bone
- Left pelvic bone to right pelvic bone
- Navel to right pelvic bone (participants pointed to their navel position over their shirt)
- Right pelvic bone to right kneecap
- Right kneecap to heel of right foot

To better compare the wheelchair-bound patients with controls, all body measures were taken using measuring tape while the participant was seated. In addition, a front-view photograph of participants was taken while participants were seated with their arms outstretched at their sides to confirm measurements.

RESULTS

By comparing perceived body part lengths across groups with differing SCI levels, we aimed to establish the effect of sensorimotor loss on the body image. Figure 3 shows each group's average body image compared to their average true body configurations. When averaged across participants, body images are similar across groups. While qualitatively interesting, these average images can be misleading because in order to properly test for group differences individual distortions must be taken into account. All analyses were therefore performed on perceived body part lengths expressed as the difference between the perceived length and the participant's true body part length, as a proportion of the true length.

The normalised perceived length of 21 body parts was calculated (see Methods). A repeated measures ANOVA with anchor (3) and body part (21) as within group factors and group (3) as a between group factor revealed a trend toward an effect of group ($F(2,39)=2.53$, $p=0.09$). Overall, perceived body part length relative to height was smallest in tetraplegic patients (0.09), slightly greater in paraplegic patients (0.13), and greatest in controls (0.18).

The ANOVA revealed a body part x group interaction ($F(40,780)=1.50$, $p=0.03$). Post hoc t-tests showed that this interaction was driven by group differences in shoulder width and hip width. Tetraplegic patients perceived their shoulder and hip widths as narrower than controls (both $p<0.01$; TPP shoulder 0.37, hip 0.18; CTL 0.69 and 0.62). That is, their body image was elongated compared to the controls. Paraplegic patients fell between the other two groups for both widths (shoulder 0.55, hip 0.36, all $p>0.10$). The ANOVA revealed no effect of anchor ($F(2,78)=0.80$, $p=0.46$), no anchor by group interaction ($F(4,78)=0.55$, $p=0.70$), and no three-way factor interaction ($F(80,1560)=1.22$, $p=0.10$).

The first analysis revealed group differences in body width relative to height, with no consistent differences in perceived limb length or torso length. However, because expressing body part lengths as a proportion of height could mask elongation effects, we further investigated distortions in the body image across groups by comparing body aspect ratios. Specifically, we calculated the following three body aspect ratios for each participant, for each anchor: torso length/hip width, arm length/shoulder width, and leg length/hip width. Ratios were then expressed as the difference between the perceived ratio and the participant's true ratio, as a proportion of the true ratio. A repeated measures ANOVA with these body aspect ratios (3) and anchor (3) as within group factors and group (3) as a between group factor revealed a main effect of group ($F(2,39)=3.38$, $p=0.04$). A Fisher's Least Significant Difference test revealed that both the paraplegic and tetraplegic groups had overall significantly greater ratios than the control group (CTL -0.27, PPP -0.09, TPP -0.08; PPP versus CTL, $p=0.04$; TPP versus CTL, $p=0.03$). The two patient groups did not differ from each other ($p=0.94$). Crucially, there was no interaction between ratio and group ($F(4,78)=1.87$, $p=0.12$), indicating that both paraplegic and tetraplegic patients overestimated all ratios relative to controls (Figure 4). This demonstrates a general perceived elongation of the body and limbs, relative to perceived width, in SCI patients relative to controls.

There was also an effect of ratio ($F(2,78)=106.02$, $p<0.01$), with torso ratios on average overestimated relative to both arm and leg ratios (post hoc t-test torso versus arm, $p<0.01$; torso versus leg, $p<0.01$) and leg ratios slightly underestimated relative to arm ratios (arm versus leg, $p=0.04$). There was neither an effect of anchor ($F(2,78)=0.14$, $p=0.87$) nor an interaction of anchor with group ($F(4,78)=0.66$, $p=0.62$) or ratio ($F(4,78)=1.66$, $p=0.16$). There was no three-way factor interaction ($F(8,156)=0.56$, $p=0.81$).

Because not all patients had complete lesions, we repeated the ANOVA including only patients with AIS grade A lesions (n=18), collapsing patients across SCI groups. This group (2) by anchor (3) by ratio (3) ANOVA revealed the same crucial result as the analysis that included grade B, C, and D lesion patients: a main effect of group ($F(1,34)=6.25$, $p=0.02$), with the SCI group showing greater ratios than the control group.

To test whether distortions in body aspects ratios were significantly different to true body distortions and not just different across groups, we compared true body aspect ratios to perceived ratios (collapsing across anchors since there were no effects or interactions of anchors in previous analysis). Paired t-tests revealed no difference between true and perceived torso ratios for controls ($p=0.77$), but overestimation for tetraplegic patients ($p<0.01$) and a trend toward overestimation for paraplegic patients ($p=0.07$). For arm and leg ratios, all groups showed significant underestimation of perceived ratios compared to true (all $p<0.01$).

To ensure that our effects were independent of lesion level and time since injury, we ran a final set of analyses in which all SCI patients were grouped together. Across all SCI patients, neither lesion level nor time since injury correlated with any of the body aspect ratios (all $p>0.15$).

When presented with a series of body templates with differing hip width/height ratios, participants in all three groups performed well at selecting the templates that most closely matched their true body dimensions (average difference between template ratio and true ratio: CTL 0.012, PPP 0.006, TTP 0.011). A 3 x 1 ANOVA revealed no main effect of group ($F(2,41)=0.88$, $p=0.43$). This demonstrates that despite the implicit distortions in the perceived relative length and width of their bodies revealed in the BIT, the paraplegic and tetraplegic patients' body images were overall as accurate as the control group when tested in a task involving recognition of a complete visual body, i.e., template matching.

DISCUSSION

We developed a novel, quantitative test of the body image, the BIT. This test involves identifying the position of one body part relative to another body part (an anchor), based on the perceived relative positions of the body parts on one's own body as if seen in a canonical view. We used the BIT to compare the perceived length of intact versus affected body parts in SCI patients compared to age-matched controls. We found that regardless of differing spinal cord injury levels, compared to controls, paraplegic and tetraplegic patients alike implicitly perceive their torso and limbs as elongated relative to their body width. If body image depended strongly on sensorimotor signals, as suggested by experimental anaesthesia studies[7;8] and amputation studies[9;10], then an effect of lesion level might be predicted. However, no such effect was found. Thus, our results suggest that chronic sensorimotor loss may not directly and specifically alter individual elements of the body image. In contrast, the global elongation of body image that we observed in SCI patients, both above and below the lesion level, could be a secondary consequence of prolonged changes in body posture, perhaps reflecting an inability to stand or walk[16].

Several studies have demonstrated that functional and structural cortical reorganisation occur following deafferentation[11-15]. In SCI it appears that cortical reorganisation is particularly associated with the growth of new intracortical connections[13;21]. Henderson et al.[13] found that primary somatosensory cortex (S1) reorganisation of the hand area toward the deafferented leg area following SCI was associated with grey matter preservation and decreased fractional anisotropy. These changes in cortical organisation may occur secondary to altered spino-thalamic and spino-cerebellar input and presumably reflect the adaptation of cortical maps to altered inputs[11].

Although sensory information clearly influences the body image[7;8], the conscious body image may be only indirectly linked to primary sensory areas. Instead, the body image is thought to predominately arise from the posterior parietal cortex (PPC), and to depend strongly on visual input. Phantom limb studies in amputees, for example, show that perceived movement of the phantom limb is associated with increased activity in PPC[22] and other non-painful phantom sensations are more linked to changes in PPC than SI[23]. Furthermore, in some cases lesions in PPC can suppress the experience of phantom limbs[24] and can induce asomatognosia, a condition in which parts of the body feel as though they have disappeared[25;26]. Other studies have shown that left PPC is involved with processing spatial information about bodies[27-29]. Patients with damage in the left PPC can exhibit autotopagnosia, an inability to localise and orient different parts of the body while maintaining the ability to identify body parts[30;31]. Despite cortical reorganisation of primary somatosensory areas, chronic sensorimotor loss may in fact not affect the body image since higher level areas such as PPC are generally unaltered following SCI. Indeed, a patient with total large-fibre deafferentation below the neck was assumed to rely on a (visual) body image to compensate for the complete absence of proprioceptive or body-schema input[32].

Our BIT results show two clear directional effects. First, limb-based body aspect ratios were systematically underestimated in all participants, suggesting that the body image represents a broader, shorter shape than the physical body. Second, our results showed a relative elongation of the body image in SCI patients. These directional effects recall recent studies of the internal representations of the hand, which revealed a systematic directional distortion of the hand being perceived as broader and the fingers as shorter than their true shape[33]. Interestingly, these distortions appear to parallel the anisotropy of receptive field shape found in SI neurons, so may reflect a somatosensory frame of reference for the internal body model. Anaesthetising body parts results in acute increases in perceived size, particularly in increased width[7;8]. Our results suggest that these same distortions may apply for the image of the body as a whole: in all groups we found that arm length/shoulder width ratios and leg length/hip width ratios from the body image were less than the corresponding ratios measured from the body itself. That is, bodies are represented as wider relative to limb length than they really are. However, contrary to previous reports of wider perceived shoulder width in SCI patients than controls[16;17], our implicit task found a subjective elongation effect in SCI patients. This suggests that the typical widening distortion is reduced in patients with SCI relative to controls. These widening distortions might be expected on the basis of somatosensory information[33], but are not consistent with a body image derived from visual sources such as viewing one's own body directly or via a mirror, or from viewing others' bodies. After prolonged sensorimotor loss, the visual contribution to the body image may be increased relative to the somatosensory contribution, leading to reduction of the somatosensory-based distortions that characterise normal internal models of the body.

Importantly, we found that lesion level in SCI patients did not predict which specific body parts were perceived as elongated. This could reflect a fundamental limitation of sensorimotor loss as an explanation for our results. One possibility is that the conscious body image may depend less on local sensorimotor traffic with individual body parts and more on the general experience of mobility and body posture as a whole – all our patients were wheelchair users, despite a range of lesion levels. Alternatively, the combination of visual and somatosensory information that produces the body image may be organised for the body as a coherent whole, rather than separately for each body part. In this context, it would be interesting in future studies to measure the internal body model before and after interventions affecting only a single body part, such as anaesthesia.

An alternative explanation could attribute the changes in body image following SCI to prolonged changes in body posture, and possibly to wheelchair use. SCI patients typically undergo extensive rehabilitation to slowly adapt to their new body state. Patients are generally in a seated or laying position and must integrate these new postures and devices into their daily lives. Studies have shown that tools can be incorporated into a user's peripersonal space[34], and tool-use can alter one's body representation[35;36]. In the specific context of wheelchair use, one recent review[37] discussed the notion that acquiring wheelchair skills results in patients altering their body representation and embodying the device. Physical and emotional adjustments that follow wheelchair confinement could result in a new body representation in which the person's physical self, as well as their feelings and actions, incorporate the wheelchair[38]. As reported anecdotally, prolonged wheelchair use and the reconstruction of one's capabilities results in the chair becoming part of a person's body representation: '[the chair] is a part of me. It's my other half. My mind is one half, the wheelchair is my body'[39]. Indeed, Arnhoff and Mehl[16] suggested that the subjective broadening of the shoulders they identified in SCI patients could reflect referencing the body width to the width of the wheelchair. It is possible that the changes in body image we see across our paraplegic and tetraplegic patients reflect the embodiment of a wheelchair into their body representations. Specifically, our data suggest that confinement to, and possibly embodiment of, a wheelchair may result in an elongated image of the body and limbs relative to body width.

Our results cannot be explained by general distortions in the ability to perceive bodies, or to recognise one's own body shape, as both patient groups performed comparably to controls on an explicit body template selection task. The body templates used in the task varied in relative width and therefore were specifically relevant for testing for explicit distortions in body aspect ratios; none were revealed. When tested with the more implicit BIT, however, distortions in body aspect ratios were observed in SCI patients. The observed elongation in SCI patients may seem paradoxical, given that a seated person has a lower overall height than the same person standing, but it is possible that being confined to a seated position may result in overcompensation of height when patients are required to imagine themselves standing. It would be interesting in future work to test whether the implicit perception of increased body and limb length relative to width is still observed if patients respond by locating body parts in a canonical seated posture, rather than a standing posture.

However, visuospatial perspective makes use of a seated canonical posture problematic: for example, the knee and hip of a seated person are very close when projected onto a 2D screen.

The BIT gives a quantitative measure of distortions of conscious body image. In addition to this body image, we are thought to also have a more unconscious body model, the body schema, which reflects more what the body is “felt” to be like as opposed to what it is “perceived” to be like[1]. One would predict that in SCI patients the body schema, which is thought to rely more on proprioceptive and tactile inputs as opposed to visual, would be considerably distorted. There is also evidence of a lexical-semantic representation of the body, which is impaired in certain stroke patients[40]. The ability of SCI patients to perform the BIT and their unimpaired performance on the template selection task suggest that lexical-semantic knowledge of their bodies remains intact.

One potential limitation of our study is that our tetraplegic patients were not completely without upper-body motor function. All tetraplegic patients, however, had significant sensory loss in their arms and below their shoulders relative to the paraplegic patients (Table 1). Furthermore, when only patients with AIS grade A lesions were analysed, we still found that patients had elongated body aspect ratios relative to controls. Crucially, this tetraplegic group allowed us to control for average body posture and device use across our patient groups, as all patients were confined to wheelchairs. Future studies should explore the body image in tetraplegic patients with complete sensorimotor loss who are unable to use manual wheelchairs. It may be interested to test responses to a lying position compared to a standing position, which from a test perspective should provide a comparable 2D image.

Chronic sensorimotor loss following SCI, and the subsequent presumed cortical reorganisation, may not directly affect body image, as changes were not related to the level of injury. Instead, changes in how the body is used and experienced on a daily basis, in this case as a result of confinement to a wheelchair, may alter one’s body image. This provides new knowledge of what information is used to form body representations. Moreover, our results have implications for rehabilitation following SCI. The ability to measure body image quantitatively with BIT may also be useful in assessing the effects of body image interventions, and in assessing changes in body image as a result of training with prosthetic devices and virtual environments.

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COMPETING INTEREST

The authors declare no competing interest.

CONTRIBUTORSHIP STATEMENT

All authors contributed to the design of the experiment. CTF, MP, and GS collected the data. CTF analysed the data. CTF, MP, MRL, and PH contributed to the writing and editing of the manuscript.

Table 1: Patient information

Group	Sex	Age	Time Since Injury (yrs)	Lesion Level	AIS grade	Motor Level		Sensory Level	
						Right	Left	Right	Left
PPP1	M	36	0.5	T3	A	T3	T3	T3	T3
PPP2	F	49	0.5	T12	A	T12	T12	T12	T12
PPP3	M	42	2.2	T10	A	T10	T10	T10	T10
PPP4	M	44	16.0	T5	A	T5	T5	T5	T5
PPP5	M	42	2.8	T3	A	T3	T3	T3	T3
PPP6	M	38	15.0	T8	A	T8	T8	T8	T8
PPP7	M	38	5.0	T12	A	T12	T12	T12	T12
PPP8	M	38	13.0	T8	A	T8	T8	T8	T8
PPP9	M	41	4.0	T9	A	T9	T9	T6	T9
PPP10	M	19	1.5	T10	A	T10	T10	T10	T10
PPP11	M	56	26.0	T5	A	T5	T5	T5	T5
PPP12	M	35	1.0	T10	A	T11	T11	T11	T11
TPP1	M	27	0.4	C6	B	T1	T1	+	+
TPP2	M	55	0.6	C6	B	T8	T8	+	+
TPP3	M	47	3.1	C8	D	T1	T1	+	+
TPP4	M	63	0.5	C6	A	C6	C6	T7	T7
TPP5	M	40	2.7	C5	A	C5	C5	C4	C4
TPP6	M	22	0.9	C7	D	C6	C5	C7	C7
TPP7	M	22	1.2	C6	A	C6	C6	C6	C6
TPP8	F	29	2.0	C6	C	C7	C6	+	+
TPP9	M	30	11.0	C5	A	C6	C6	C5	C5
TPP10	M	29	11.0	C6	C	C6	C6	C8	C8
TPP11	M	41	10.0	C6	A	C6	C6	C8	C8

TPP12	M	31	1.5	C6	A	C6	C6	C6	C6

Abbreviations: PPP = paraplegic patient; TPP = tetraplegic patient; AIS = Abbreviated Injury Scale; + = conserved function

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