

ORIGINAL ARTICLE

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Cardiovascular responses at the onset of passive leg cycle exercise in paraplegics with spinal cord injury

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Abstract The purpose of this study was to examine the cardiovascular responses at the onset of passive leg cycle exercise (PLCE) in paraplegics with spinal cord injury (PSCI) to investigate the increase in venous return from the paralyzed lower limbs during PLCE. Six male PSCI having lesions at levels ranging from T8 to L1 and five male able-bodied subjects (ABS) participated in this study. The subjects performed PLCE at pedalling frequencies of 40 rpm for 6 min. Cardiac output (\dot{Q}_c), stroke volume (SV) and heart rate (f_c) were measured before and during PLCE. In the steady state (4th and 5th min) of PLCE, both PSCI and ABS showed a significant increase in \dot{Q}_c . At the onset of PLCE, however, clear differences in the cardiovascular response were found between PSCI and ABS. The ABS showed a rapid and marked increase in f_c and consequently \dot{Q}_c within 20 s of the onset of PLCE. On the other hand, in PSCI, the \dot{Q}_c increased more slowly, compared with that in ABS, because of a smaller increase in f_c and a delayed increase in SV. The observed delay in the increases of \dot{Q}_c and SV at the onset of PLCE in PSCI was presumably due to the absence of afferent reflexes from the lower limbs, and to the additional time needed for venous return to arrive at the heart from the passively moved muscles.

Key words Spinal cord injury · Passive exercise · Cardiovascular response · Venous return · Paralyzed lower limbs

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Introduction

We have previously investigated cardiovascular responses during passive cycling exercise of the paralyzed lower limbs in paraplegics with spinal cord injury (PSCI; Muraki et al. 1996). That study demonstrated significant increases in cardiac output (\dot{Q}_c) and stroke volume (SV) with no increase in heart rate (f_c) during passive exercise at a steady state in PSCI. Based on these results, we have speculated that rhythmic lengthening and shortening of the paralyzed muscles by passive exercise would promote venous return from the muscles.

It has been demonstrated that in able-bodied subjects (ABS), cardiovascular responses are changed by passive exercise (Benjamin and Peysner 1964; Nakazono and Miyamoto 1985; Nobrega et al. 1994; Nurhayati and Boutcher 1998). It has been considered that these changes are mainly due to peripheral afferent reflexes (Nobrega and Araujo 1993; Nobrega et al. 1994) and to the increased venous return from passively moved muscles (Nakazono and Miyamoto 1985; Nobrega et al. 1994). In particular, rapid changes at the onset of exercise have been assumed to be controlled by afferent reflexes from the mechanoreceptors in the moved muscles (De Meersman et al. 1998; Mitchell 1990; Nobrega and Araujo 1993; Williamson et al. 1995). On the other hand, PSCI have no afferent reflexes from the paralyzed lower limbs, since the afferent pathway is interrupted by the spinal cord injury. Therefore, if increases in \dot{Q}_c and SV during passive leg exercise were to be mainly due to increased venous return from the paralyzed lower limbs, the beginning of these increases may be delayed in PSCI compared with ABS.

Cardiovascular responses at the onset of passive leg exercise in PSCI have previously been reported by Morikawa et al. (1989) who failed to show changes in cardiovascular responses at the onset of exercise in ABS as well as PSCI. Nobrega et al. (1994) have observed significant changes in the cardiovascular response during passive leg exercise using cycling movement in ABS, and

have suggested that the passive knee extension used by Morikawa et al. (1989) was less effective in increasing venous return compared with cycling movements. Thus, passive cycling movements may be more effective in promoting circulation in passively moved muscles, compared with knee extension movements. To the best of our knowledge, however, no studies have examined the cardiovascular response at the onset of passive exercise using leg cycling movement in PSCI.

The purpose of this study, therefore, was to compare cardiovascular responses at the onset of passive leg cycle exercise (PLCE) between PSCI and ABS, to investigate any differences in the rate of increase in venous return from the paralyzed lower limbs during PLCE.