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SYSTEMATIC REVIEW OF THE EFFECTIVENESS OF SPACEFLIGHT PASSIVE COUNTERMEASURES

Abstract

PURPOSE: With planning underway for future long-duration space missions (LDSMs), physiologic deconditioning represents a significant barrier to astronaut health and mission success. For decades, countermeasures have been developed, tested and used to limit deconditioning during spaceflight from gravitational unloading. Passive countermeasures work to restore normal physiologic function during microgravity through various mechanisms which do not require the exertion of effort by the user. To our knowledge, no previous systematic review has been conducted to examine the effectiveness of standalone passive countermeasures. By understanding passive countermeasure effectiveness, insight may be gained as to future directions for the research and development of countermeasures which will benefit astronaut health and mission success during LDSMs. METHODS: An initial search for literature conducted in 2017 was supplemented with an updated search conducted in 2021. Both ground-based analogue and spaceflight studies were included in these searches. A total of 647 articles were screened with 16 being included for review. Data extraction, analysis of effect sizes, and bed-rest transferability scoring were accomplished using dedicated tools built by the Aerospace Medicine Systematic Review Group. Quality of literature was assessed based on Cochrane guidelines. RESULTS: Effects of various passive countermeasures on 180 cardiopulmonary and musculoskeletal outcomes were analyzed. Of these, 20 were shown to have positive effects from intervention with a passive countermeasure compared to a passive control group. Of these, lower-body negative pressure (LBNP), skin-surface cooling and centrifugation were seen to have positive effects on orthostatic tolerance. Low-magnitude mechanical stimulation showed positive effects on balance-related outcome measures. Contradicting positive vs. no effects were seen for LBNP on heart rate and for centrifugation on VO2max. Mostly, passive countermeasures were seen to have no significant effect (159) on reported outcomes. Statistical power of results was poor due to poor quality of studies from high or unclear risk of biases, scarcity of studies, and heterogeneity of outcome measures. Bed-rest transferability was widely varied with a median score of 5 of a total attainable score of 8. CONCLUSIONS: Overall, standalone passive countermeasures have minimal effects on cardiopulmonary and musculoskeletal outcomes when used to counteract physiologic deconditioning form gravitational unloading. These observed results are limited by the heterogeneity between the examined studies, their poor quality from high and unclear risk of bias, and variable bed-rest transferability. Standardization and strict adherence to Cochrane and International Academy of Astronauts guidelines can improve the quality, statistical power and applicability of future countermeasure studies.