The effect of early exercise on intracranial pressure in neurocritical patients: a systematic review

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Abstract

Background: Neurocritical patients commonly present with increased intracranial pressure and are regularly treated with physiotherapy through exercise early after admission to the intensive care unit. However, the effect of exercise on intracranial pressure is minimally investigated, and there appears to be no systematic reviews or meta-analyses addressing this topic in the published literature. This study aimed to determine the effect of exercise on the intracranial pressure of neurocritical patients. **Methods:** Through a systematic review, literature searches on PubMed, PEDro, and CENTRAL were conducted in January 2020. The keywords used were: “physical therapy”, “physiotherapy”, “exercise”, “range of motion”, “intracranial pressure”, and “ICP”, combined using Boolean operators “OR” and “AND”. Only studies published in the English and Indonesian language were considered.

Results: A total of five studies involving 193 patients (mean age 41-56 years old) were included in this review. Most included studies reported that intracranial pressure did not change significantly after passive range of motion exercise, and some studies found that intracranial pressure actually decreased significantly during and after passive range of motion and active exercise. An additional finding was that isometric exercise significantly increased mean intracranial pressure in patients with normal intracranial pressure. All studies reported that exercise could be used safely in patients.

Conclusion: Exercise, in particular passive range of motion, does not increase the intracranial pressure of neurocritical patients and does not lead to any adverse effects, as long as isometric or Valsalva-like maneuvers are avoided.

Keywords: Exercise, Intensive care unit, Intracranial pressure, Physiotherapy

Introduction

Patients with severe cerebral diseases or injuries, such as cerebral infarction, intracerebral/cerebral hemorrhage, and traumatic brain injury (TBI), commonly present with increased intracranial pressure (ICP) that can affect patient outcome.¹ Increased ICP can result in decreased cerebral perfusion pressure (CPP) causing cerebral ischemia,² or cause herniation of the brainstem or other vital structures, which may lead to deleterious neurological damage or even brain death in severe cases.^{3,4} Consequently, monitoring and controlling ICP is essential in neurocritical care.

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Neurosurgical patients are prone to a wide variety of complications that could occur as a result of immobilization, such as contractures, deep vein thrombosis,⁵ muscle wasting,⁶ and pulmonary complications.⁷ Thus, patients are regularly treated with physiotherapy early after admission to the ICU, as recommended by the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients.⁸ Physiotherapy interventions provided can include passive and active exercises, and respiratory/chest physiotherapy such as postural drainage, tapping, vibrocompression, vibration, increased expiratory flow rate (IEF) and endotracheal aspiration (ETA) techniques.

A systematic review⁹ concluded that respiratory physiotherapy (maneuvers that included airway clearance and ETA techniques) lead to increased ICP in critically ill patients admitted to the ICU. However, although standard physiotherapy through passive and active exercise is often provided in the ICU, there is limited research regarding exercise in patients in the acute phase of cerebral diseases or injuries. There is still a common fear of harming critically ill patients with elevated ICP, which often results in “minimal handling” of patients.^{10,11} Hence, it is important to know whether exercise is safe to conduct without any detrimental effects on ICP in this category of patients to relieve the fear of harming the patient.

Currently, there are no systematic reviews or meta-analyses in the published literature addressing the effect of exercise on ICP in neurocritical patients. Therefore, this systematic review aimed to examine the effect of exercise on ICP in neurocritical patients.

Method

This systematic review was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.¹²

Eligibility Criteria

The inclusion criteria of this review were: 1) study participants were neurological-neurosurgical patients with ICP monitoring; 2) the intervention provided was exercise, where exercise interventions were defined as passive range of motion (PROM) or passive exercise and active exercise. PROM or passive exercise was defined as repeated movements of a joint within the range of that joint performed by the physiotherapist, while active exercise was defined as repeated movements of a joint within the range of that joint performed by the patient; 3) the outcome was ICP value; and 4) studies published in English or Indonesian. Dissertations, thesis, literature reviews, case

reports, letters, abstracts, studies using animal models, and studies published in other languages were excluded.

Information Sources and Search Strategy

The literature search was conducted using the keywords: “physical therapy”, “physiotherapy”, “exercise”, “range of motion”, “intracranial pressure”, and “ICP”, which were combined using Boolean operators “OR” and “AND” in PubMed, Physiotherapy Evidence Database (PEDro), and Cochrane Central Register of Controlled Trials (CENTRAL) from database inception to January 2020. An example of the search strategy for use in CENTRAL can be seen in Table 1.

Table 1. Example search strategy for use in CENTRAL

#	Search
1	Physical therapy
2	Physiotherapy
3	Exercise
4	Range of motion
5	{OR #1-#4}
6	Intracranial pressure
7	ICP
8	{OR #6-#7}
9	{AND #5, #8}
	Limits:
	Trials, All dates, All years

Study Selection

Following the literature search, all identified citations were imported into Mendeley and duplicates removed. The titles and abstracts of the articles were reviewed against the eligibility criteria of this review; articles were rejected if their title and abstract provided sufficient information that they were not relevant. The results of the search were reported in full in the final report and presented in a PRISMA flow diagram 12 - see Figure 1.

Data Collection Process and Data Items

Data of study population, intervention, and outcome were extracted using the Joanna Briggs Institute (JBI) Data Extraction Form for Experimental/Observational Studies.

Data Synthesis

The findings of the included studies were summarized and a narrative synthesis approach was undertaken.

Assessment of Methodological Quality

Relevant studies were retrieved in full and were critically appraised for methodological quality by two reviewers (SAPT and PEM) using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (non-randomized experimental studies), which consists of nine questions to evaluate the study’s research design and validity of results.¹³ The included articles were classified as “high quality” if they achieved a total score of ≥ 5 or as “low quality” if they

scored ≤ 4 . The total score was used to indicate the methodological quality of the articles and was not used as an inclusion or exclusion criteria. No disagreements occurred among review authors.

Result

Figure 1 shows the number of records identified, included and excluded. A total of 284 articles were identified, with 210 remaining after duplicates were removed. Following the screening of these articles, a total of five articles appeared to be relevant to this review and were retrieved in full-text.

Figure 1. PRISMA flow diagram

Table 2 shows the critical appraisal results of the included studies. All studies were clear regarding the “cause” (exercise) and “effect” (ICP) explored, compared the results of measurement before and after the intervention/treatment, had complete follow-up of participants, used reliable outcome measures, and used appropriate statistical analyses. All but one study¹⁴ included participants that were similar in terms of characteristics. One study involved a control group of healthy individuals for the purpose of comparing the results. As this study¹⁴ involved a healthy control group, there were differences in the characteristics of participants and treatment/care provided in the compared groups, and outcomes in the control group were measured differently compared to the patient group. The remaining studies compared the results between periods (before, during, and after the

intervention). Four studies achieved a score of 8/9 and one study obtained a score of 6/9, meaning that all studies were classified as “high quality” quasi-experimental studies.

Table 2. Critical appraisal results of included study.

JBIC Checklist Criteria	Koch <i>et al.</i> ⁵	Brimioulle <i>et al.</i> ¹⁵	Thelandersson <i>et al.</i> ¹⁴	Roth <i>et al.</i> ¹⁰	Thelandersson <i>et al.</i> ¹⁶
1 Clear ‘cause’ and ‘effect’	Yes	Yes	Yes	Yes	Yes
2 Similarity of participants in compared groups	Yes	Yes	No	Yes	Yes
3 Similarity of treatment/care in compared groups	Yes	Yes	No	Yes	Yes
4 Existence of a control group	No	No	Yes	No	No
5 Existence of pre- and post-intervention measurements	Yes	Yes	Yes	Yes	Yes
6 Complete follow-up or procedures of any follow-up measures	Yes	Yes	Yes	Yes	Yes
7 Outcomes measured in the same way for compared groups	Yes	Yes	No	Yes	Yes
8 Reliability of outcome measures	Yes	Yes	Yes	Yes	Yes
9 Appropriateness of statistical analysis	Yes	Yes	Yes	Yes	Yes
Total score	8/9	8/9	6/9	8/9	8/9

The details of study characteristics are provided in Table 3. The five studies included a total of 193 participants between the mean age of 41 and 56 years. Individual sample sizes of these studies ranged from 12 to 84. All studies involved patients of both genders with neurological-neurosurgical disease treated in the neuro-ICU. The majority of studies provided exercise in the form of PROM,^{5,10,14,15} while one also provided active exercise,¹⁵ and another study¹⁶ provided bedside cycle exercise using a bedside cycle ergometer for both passive and active exercise.

Besides ICP, other haemodynamic variables such as CPP, mean arterial pressure (MAP), blood pressure (BP), heart rate (HR), and systemic arterial pressure (SAP) were also considered as outcomes in the studies included in this review. However, this review specifically focused on presenting the results of the effects of exercise on ICP.

Two of the five studies showed significant decreases in ICP during PROM when compared to before PROM.^{10,14} Two studies^{14,15} found significant decreases in ICP after PROM when compared to before PROM; more specifically, Brimioulle *et al.*,¹⁵ reported that in

patients with normal ICP, PROM decreased mean ICP significantly in the supine position but not in the head-up position (30 and 45 degrees), while patients with high ICP experienced a significant decrease in ICP in the 30-degree head-up position during active exercise.

On the other hand, one study¹⁶ found no significant changes during and after exercise using a bedside cycle compare to before exercise. Similarly, three other studies^{5,10,15} showed no statistically significant changes in ICP before versus after PROM exercise.

One study¹⁵ reported that isometric hip adduction lead to an increase in the mean ICP of patients with normal ICP, but did not affect the ICP of patients with high ICP.

With regards to CPP, none of the studies that examined CPP found any significant differences during and after exercise when compared to before exercise, although Brimiouille *et al.*,¹⁵ did find that PROM exercise performed in the supine position actually increased CPP in patients with normal ICP. However, one study¹⁶ did show significant decreases in CPP after exercise using a bedside cycle when compared to during exercise.

With regards to safety, all studies reported that exercise could be used safely in patients with neurological-neurosurgical diseases, provided that resistance or Valsalva-like maneuvers are avoided. None

of the studies reported any adverse events during the implemented exercise.

Discussion

This review confirmed the limited number of studies investigating the effect of early exercise on the ICP of neurocritical patients, despite physiotherapy being regarded as standard therapy that is frequently applied in neuro-critical care units.

Most studies included in this present review showed that ICP in neurocritical patients did not change significantly after PROM exercise, and some studies found that exercise actually lead to a significant decrease in ICP values during and after PROM and active exercise without significantly changing CPP values. However, one study¹⁵ found that that isometric exercise (hip adduction) significantly increased mean ICP in patients with normal ICP, but did not affect the ICP of patients with high ICP. Therefore, the studies analyzed in this review indicated that performing PROM and active exercise in neurocritical patients does not lead to increased ICP and can be safely used in neurocritical patients with normal or high ICP, provided that isometric or Valsalva-like maneuvers are avoided. However, it must be noted that the majority of studies included in this systematic review are classified as level 2.d

Table 3. Characteristics of selected studies

Author	Sample (N)	Sample characteristics	Intervention	Key variables	Significant outcomes
Koch <i>et al.</i> ⁵	12 patients	<ul style="list-style-type: none"> Neurosurgical-neurological disease 6 mechanically ventilated, 6 spontaneous breathing Mean age 49.42 years GCS 7±1.3 in mechanically ventilated, GCS 13±0.8 in spontaneous breathing 	PROM (20 PROM sessions - mechanically ventilated 10 PROM sessions; spontaneous breathing 10 PROM sessions) Average duration: 7±1 minutes	ICP CPP (MAP-ICP) MAP HR RR	<ul style="list-style-type: none"> There were no statistically significant changes in any variables
Brimioulle <i>et al.</i> ¹⁵	65 patients	<ul style="list-style-type: none"> Admitted to neuro-ICU 42 comatose Normal ICP (<15 mmHg): N = 30, mean age 41 years, GCS 6 High ICP (>15 mmHg): N = 12, mean age 44 years, GCS 5 23 conscious Normal ICP (<15 mmHg): N = 15, mean age 56 years, GCS 14 High ICP (>15 mmHg): N = 8, mean age 51 years, GCS 13 	PROM (each movement repeated passively 10 times/minute for 2 minutes) Exercise (all exercise repeated actively 10 times/minute for 2 minutes)	ICP CPP HR SAP	<ul style="list-style-type: none"> PROM decreased ICP in supine position (p<0.05) PROM decreased ICP (P<0.01) in patients with high ICP Exercises did not affect ICP in patients with normal ICP In patients with high ICP, exercises and decreased ICP (p<0.05) during upper-limb movements Isometric hip adduction increased mean in patients with normal ICP but not in patients with high ICP
Thelandersson <i>et al.</i> ¹⁴	12 patients; 12 healthy controls	<ul style="list-style-type: none"> Severe head injury admitted to neuro-ICU, mechanically ventilated Normal ICP (N=5), high ICP (N=7) Median age 43±19 years 	PROM (5 days a week, 1 set per joint and 5-10 repetitions per joint in sedated patients without increased muscle tone)	ICP CPP HR	<ul style="list-style-type: none"> In the patient group, ICP reduced significantly during and after PROM
Roth <i>et al.</i> ¹⁰	84 patients	<ul style="list-style-type: none"> Admitted to neuro-ICU 98% mechanically ventilated, 2% spontaneous breathing Mean age 55±15 years GCS 6.4±4.3 	PROM (26 minutes once a day)	ICP CPP HR MAP	<ul style="list-style-type: none"> Overall, mean ICP decreased significantly during therapy Patients with normal ICP (<15 mmHg) and high ICP (>15 mmHg) experienced significant decrease in ICP during therapy No significant difference in ICP was seen before and after PROM in all groups
Thelandersson <i>et al.</i> ¹⁶	20 patients	<ul style="list-style-type: none"> Brain injuries or stroke admitted to neuro-ICU Mean age 49±18 years GCS 6±3 	Bedside cycle exercise (20 minutes)	ICP CPP MAP HR	<ul style="list-style-type: none"> There were no significant differences in any variables before and after exercise, including ICP

CPP: cerebral perfusion pressure; GCS: Glasgow Coma Scale; HR: heart rate; ICP: intracranial pressure; ICU: intensive care unit; MAP: mean arterial pressure; PROM: passive range of motion; RR: respiratory rate; SAP: systemic arterial pressure

evidence according to the JBI levels of evidence for effectiveness questions.¹⁷

As stated by Roth *et al.*,¹⁰ the mechanism in how ICP is reduced during physiotherapy is still unclear, and publications regarding the changes of cerebral hemodynamics are rare in the literature. It is possible that movements of the limbs from exercise may result in a decrease in ICP due to improved drainage of the cerebral venous system.¹⁰ Moreover, it has been proposed that the decrease in ICP during PROM exercise could be caused by sensory stimulation and improved consciousness that were induced from passive ROM, as sensory stimulation has been shown to decrease ICP in a previous study.¹⁵

On the other hand, some studies in this review found no significant difference in ICP after PROM exercise. The most logical explanation for this would be because exercise and movements of the extremities have ceased, so the ICP value returned to their baseline level. In addition, Thelander *et al.*,¹⁶ presumed that the reason passive exercise using a bedside cycle ergometer did not affect ICP in their study could be caused by the absence of sensory stimulation from the cycle ergometer when compared to sensory stimulation experienced by the patient from PROM provided by a physiotherapist.

A previous systematic review⁹ found that respiratory/chest physiotherapy (maneuvers that included airway clearance and ETA techniques) lead to increased ICP in critically ill patients admitted to the ICU. In contrast to this, our review found that physiotherapy in the form of passive and active exercise did not lead to increased ICP. The difference in results could be due to the difference in the nature of respiratory/chest physiotherapy interventions applied to the chest and exercise provided to the extremities/limbs, and the mechanism in how they affect cerebrovascular and hemodynamic parameters.

The present review has several limitations. The studies included in this review only evaluated the short-term changes in cerebrovascular and hemodynamic parameters; thus, the long-term effects are still unknown, particularly with regards to important clinical outcome parameters such as duration of ICU stay and Glasgow Outcome Scale. Grey literature was not searched, which may lead to publication bias towards a selection of positive results, and only studies published in English were included, so relevant studies published in other languages may have been omitted. Additionally, there were no randomized controlled trials comparing the outcome of patients who received exercise and those who did not; hence it cannot be said for sure that the changes in ICP were solely due to exercise and were not related to other factors. Furthermore, the majority of studies had small sample sizes,

thereby limiting the external validity of their findings.

Conclusion

In conclusion, this systematic review verifies the very limited number of studies addressing the effect of exercise on the ICP of neurological-neurosurgical patients in the ICU. The evidence available in the current literature indicates that exercise, in particular PROM, does not increase the ICP of this patient population and does not lead to any adverse effects, as long as isometric or Valsalva-like maneuvers are avoided. However, more well-designed studies with larger sample sizes in this category of patients are needed.

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