Comparative Effects Of Russian Current And Isometric Resisted Exercise On Quadriceps Angle And Joint Space Width Among Patients With Primary Knee Osteoarthritis

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Abstract: Background: Beneficial effects of Isometric Resisted Exercise (IRE) in the rehabilitation of patients with primary Knee Osteoarthritis (OA) are sometimes restricted due to associated co-morbidities. Objective: This study compared the effects of Russian Current (RC) and IRE in the management of patients with primary knee OA. Methods: A hospital-based quasi-experimental study was conducted in a tertiary hospital in Osun State. Forty-seven consenting patients with knee OA participated in this study. They were randomly assigned to either IRE only (IREO) group or IRE plus RC (IRERC) group. Each participant received treatment twice a week for a total of eight weeks. Effects of intervention were assessed in terms of quadriceps angle and joint space width at the 4th and 8th week of intervention. Data were analyzed using descriptive and inferential statistics with alpha set at p<0.05. Result: IRERC and IREO resulted in a significant mean change in quadriceps angle (IRERC – p=0.005; IREO – p=0.001) score. However, there was no significant mean change in joint space width of both groups (IRERC – p=0.334; IREO – p=0.433). Furthermore, there was no significant difference in the mean changes in quadriceps angle and joint space width scores between IRE plus RC and IRE only groups (p>0.05). Conclusion: Isometric resisted exercise alone had a significant effect on quadriceps angle in patients with primary knee OA. However, Russian current did not show additional effects.

Keywords: Electrical stimulation, Isometric resisted exercise, Primary knee Osteoarthritis, Russian current

1. Introduction
Knee osteoarthritis (OA) is characterized by degeneration of normal cartilage which is progressive and debilitating due to irreversible changes in the matrix structure of the joint [1]. Pathological changes in cartilage structure with radiological evidence of osteophytes and narrowing joint space resulting in perceived pain and in extreme cases disability are all classical signs of knee OA [2]. The rate of knee OA increases with age with females more predisposed to knee OA than their male counterparts [3]. Knee OA can be classified as either primary or secondary. Identifiable risk factors for primary knee OA include aging or heredity even though the majority of cases are idiopathic [4]. Joint degeneration triggers like infections, congenital deformity, trauma including repetitive micro-trauma due to certain occupations like football or farming are the risk factors seen in secondary knee OA [2], [4]-[5]. Amongst the earliest symptoms of knee OA is pain, which is mainly a dull aching pain occurring intermittently and during periods of inactivity. This later progresses to a cramp-like pain occurring continuously usually after activity [6]. Pain, either acute or chronic lead to a reduction in joint range of motion and quadriceps weakness which in turn could result in disability particularly the older age group [7]. The etiology and progression of knee OA are mainly due to weak quadriceps which leads to an undue stress across the knee [3]. Abnormal quadriceps-angle (Q-angle) can result in a weak quadriceps apart from knee pain. The Q-angle is the angle between the quadriceps muscles (primarily the rectus femoris) and the patellar tendon and represents the angle of the quadriceps muscle force [8]. The normal Q-angle for healthy men is 13 degrees while for women is 18 degrees [9]. In Nigeria, a study was conducted to find out if these angles were also seen in the general population. The result showed that both the Nigerian and Caucasian men had the same Q-angle while the Nigerian women had an average of 3 degrees more than that of Caucasian women [10]. An increased Q-angle away from the normal values has been linked to weak quadriceps especially the medial quadriceps [11], while a decreased Q-angle may result in an increased pressure to the tibiofemoral joint medially thereby increasing the varus orientation [12]. Joint space narrowing (JSN) occurs due to the erosion of the cartilage as part of the degenerative process associated with arthritis but the best method of evaluating the progression of the cartilage destruction is through measurement of joint space width...
articular steroid injections to knee within three months prior to the study.

2.2 Procedure
Ethical approval was obtained from the Ethics and Research Committee of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC) Ile-Ife, Nigeria. Approval was also obtained from the head of the Physiotherapy department. Participants gave written informed consent after the purpose and protocol of the study had been explained to them. Each participant who satisfied the eligibility criteria was then given a study number in order to ensure confidentiality. All information collected from participants were encrypted in an electronic file and protected by a password. Only the principal researcher had access to all collected data. Forty-seven participants were consecutively recruited and randomly assigned into two different treatment groups using a permuted block program [24]. This block randomization online program used a block size of four. The first group of participants received a combination of Isometric Resisted Exercise and Russian Current (IRERC) to the quadriceps of the affected knee joint while the second group of participants received Isometric Resisted Exercises only to their involved knee joint (IRE). Each participant received treatment twice per week for eight weeks.

2.3 Instruments
A stadiometer manufactured by Leidal Medical Ltd, the United Kingdom with model number: RGZ-160 was used to measure both the weight and height of each participant in kilograms and meters respectively. An electrical stimulation machine, Sonopuls 692 made by Enraf-Nonius Company. The Netherlands with model number: 160/945 was used to stimulate the quadriceps of participants with knee OA in the second group.

2.4 Measurement

Height
Height measurement was done with a stadiometer in meters to the nearest centimeter. Each participant stood on the weight measure erect, with shoes off while their occiput touched the metering rod. This measuring rod was carefully placed on the highest point of each participants head which is perpendicular to the height meter [25].

Weight
Each participant weight was measured in kilogram (Kg) to the nearest 0.1kg. Each participant stood on the stadiometer with shoes off while wearing a light apparel. Each participant was asked to look forward while reading was recorded [25].

Body Mass Index (BMI)
Participant’s BMI which is in kilogram per meter squared (Kg/m²) was calculated using the participant’s weight measured in kilograms and diving it by the square of the appropriate height in meters. Classification of the BMI was done according to WHO (2000) recommendations [26]. The BMI values are as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>BMI Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.50 Kg/m²</td>
</tr>
<tr>
<td>Normal</td>
<td>18.50 - 24.99 Kg/m²</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.00 - 29.99 Kg/m²</td>
</tr>
<tr>
<td>Obese Class I</td>
<td>30.00 - 34.99 Kg/m²</td>
</tr>
<tr>
<td>Obese Class II</td>
<td>35.00 - 39.99 Kg/m²</td>
</tr>
<tr>
<td>Obese Class III</td>
<td>≥ 40 Kg/m² and above</td>
</tr>
</tbody>
</table>

2. Methods

2.1 Participants
Participants in this hospital-based quasi-experimental study design were forty-seven in number. They were diagnosed with primary osteoarthritis of the knee joint and referred from the outpatient orthopedic clinic of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife and Ilesha Units. The participants were then recruited from the outpatient physiotherapy clinics of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife and Ilesha Units, Osun State. Eligibility for inclusion were patients with knee OA whose ages were 40 to 75 years of age; grade III OA according to Kellgren and Lawrence classification; unilateral and/or bilateral OA of the knee (However, the knee joint with the greater symptoms was considered for patients with bilateral knee OA). Exclusion criteria included patients with secondary knee OA due to traumatic injury or infection; any absolute or uncontrolled cardiovascular contraindications to exercise; any current severe neuromuscular disorders; any recent surgical interventions, metallic implants and Inserted (JSW) [13]. The JSW is assessed by measuring the inter-bone distance at its narrowest point referred to as minimum JSW. Two methods had been used as a radiographic assessment method to measure the rate of progression of knee OA. They are the anteroposterior (AP) view with the knees extended and the Lyon schuss view which is a posteroanterior (PA) radiographic view with the knees flexed from 10° to 30° depending on the relative length of the feet and tibias. Both radiographic views are taken in a standing position [13]. The treatment method employed in the management of patients with knee OA is mainly divided into two: non-invasive treatment including pharmacology and physiotherapy and the invasive method such as surgery [14]. Physiotherapy intervention has been proven to be effective as a means of treating knee OA [15], [16] with the sole aim of reducing pain, strengthening weak muscles, increasing joint range of motion, joint function restoration and deformities prevention [17]. Modalities used by the physiotherapist includes exercise therapy, cryotherapy, electrotherapy, manual therapy, foot orthosis, brace, tapping, and education on self-care [7], [15]. Isometric Resisted Exercises (IRE) to the quadriceps has been shown to be an effective management in patients with knee OA with some studies claiming that IRE delays degenerative changes and enhances the rate of daily living [18], [19]. However, most patients are unable to perform the isometric resisted exercise type to a point of benefit due to co-morbidity like cardiac disease and high blood pressure [20]. Consequently, the introduction of other intervention as an adjunct to isometric resisted exercises has been suggested [21]. Russian current was first used on Russian athletes to improve muscle strength [22] but has also been reported to reduce pain [23] and improve physical function [23]. However, a few studies had been conducted on Russian current in the management of patients with primary knee OA. Therefore, the objective of this study was to compare the effects of Russian current and IRE on quadriceps angle and joint space width amongst patients with primary knee OA with a view of finding out if Russian current could be used to augment exercise in patients with primary knee OA.
Quadriceps angle

A Baseline trademark 30cm absolute + axis Goniometer was used to assess the knee Q-angle of each participant. The midpoint of the patella was determined by first using a tape (Butterfly measuring tape made by Shanghai Kearing Stationary Co. Ltd, China with model number HD1516 of 150cm / 60 inches) to measure the patella’s length in which the midpoint was marked, then the height (the apex and base) of the patella was measured with the same tape measure and the midpoint marked. The intersection represents its midpoint. The Q-angle was then obtained by drawing an imaginary line from the Anterior Superior Iliac Spine (ASIS) to the midpoint of the patella and from the tibial tubercle to the midpoint of the same patella. The angle formed by the intersection of both lines is the Q-angle and was measured using a goniometer [27].

Joint space width

Each participant was required to take a radiographic imaging of their involved osteoarthritic knee joint. As for participants with both knees involved, radiographic imaging of both knees was taken but the more affected knee was recorded. The postero-anterior radiographic imaging was done with the participants in standing position, with their knee joint slightly flexed to 30° and patellae pressed against the imaging plate. Once the radiographic images are taken and the film released, the minimum joint space width was then measured. The medial joint space width was assessed by measuring the inter-bone distance (between the femur and tibia bone) at its narrowest point using a 0.1-mm graduated magnifying lens laid over the radiograph [28], [29].

Intervention using Isometric Resisted Exercise (IRE)

Three specific open chain IRE were completed by every participant in both groups. The resistance used were free weights to the osteoarthritic leg but if bilateral knee OA was present, the most symptomatic leg was then selected for the study. The exercises that each participant underwent included:

1. Knee extension while in a high seated position – The starting point was the arthritic knee in 90 degrees of flexion followed by verbal instruction given by the therapist to the participant to extend his / her affected leg against pre-determined ankle weights.

2. Knee extension with an instruction to hold at 30 degrees of knee flexion while in a high seated position – The starting point with the arthritic knee in 90 degrees of flexion, each participant was verbally instructed to extend / straighten their affected leg against a pre-determined ankle weight and told to hold this position once the knee flexion was at 30 degrees.

3. Straight Leg Raise (SLR) while in a supine lying position – Each participant while in a supine lying position will raise the affected / arthritic leg (knee joint) to 30 degrees hip flexion against pre-determined ankle weights [30].

The free ankle weights used were pre-determined for each consenting participant in this study by using the progressive resistance exercise program which was on ten Repetition Maximum (RM) as suggested by Thomas Delome [31]. By definition, an RM is simply “the greatest amount of weight or load a muscle can move through the full, available range of motion with control a specific number of times before fatigue sets in” [32]. Each participant 10 RM was determined, documented and then told to come back after a week to commence the strength training. Each participant after checking their blood pressure to be sure they are fit for such an exercise program were instructed to perform a warm-up exercise by riding on a bicycle ergometer without resistance applied for five minutes. Once the warm-up session was completed the resisted exercise sessions began with the first set of 10 repetitions at 50% of 10RM, a second set of 10 repetitions at 75% of 10RM and a third set of 10 repetitions at 100% of 10RM [31]. Therefore, each participant performed a total of 30 repetitions for each of the previously described knee/hip joint positions. A rest period of 120 seconds in between each set was given. The exercises were performed slowly but in a systematic manner and at each given end range the position was sustained for five seconds but later increased to 10 seconds. Constant instructions were given to each participating participant to sustain breathing throughout the phase of the exercise to avoid Valsalva maneuver [30], [33]. Once the participant is observed to have adapted to the free ankle weights, a progressive increase was made [32]. A cool down session was also performed at the end of the IRE session using the bicycle ergometer without resistance applied for five minutes. All IRE was done with tolerable levels of pain [30].

Intervention using Russian Current (RC)

Participants who were randomly selected from the second group also received RC stimulation (IRERC) to their quadriceps after resting for a period of 10 minutes following the RE intervention. Each participant in this group was positioned in a supine lying position on a plinth with reasonably sized pillows placed underneath the knee joint. Carbon rubber electrodes (8 x 12 cm) of equal paired size were placed first placed in a moist pad before placing them on the rectus femoris and vastus medialis muscles of the arthritic knee joint and held in place by a Velcro strap. A carrier frequency of 2,500Hz alternating sinusoidal waveform current with a burst frequency at 50Hz was used. The intensity was then gradually increased until there was a maximum but tolerable strong quadriceps contraction. Once it was observed that neural accommodation has occurred, the amplitude was further increased to produce the strong contraction but at a comfortable sensory level for each participant[3]. The electrical stimulation was given for a duration of 10 minutes using the regimen 10/50/10 – meaning 10 seconds “on”, 50 seconds “off” and this sequence is repeated in 10 minutes [34]. Participant in this group had their quadriceps stimulated twice a week for 8 weeks.

3 Data analysis

Normality testing for dependent variables was done using Shapiro-Wilk test. Continuous variables such as age and height were summarized using mean (standard deviation). Inferential statistics of repeated measure of Analysis of Variance (ANOVA) was used to compare quadriceps angle and joint space width of each of the two groups across baseline, 4th and 8th week. Post hoc analysis of Fisher’s Least Significant Difference (LSD) was used to identify which pair of means of quadriceps angle were statistically different in each of the two groups at baseline, 4th and 8th.
week. Student t-test was also used to compare the mean changes in quadriceps angle and joint space width between the IRE only group and the IRERC group. Data were analyzed using the Statistical Program for Social Sciences for Windows version 22 (SPSS Inc., Chicago, Illinois, United States) and cut-off statistical level of significance was set at P < 0.05.

4. Results
The mean (standard deviation) age, height, weight, and body mass index of participants who took part in this study were 61.30(10.58) years, 1.59(0.07) m, 82.00(10.77) Kg and 32.81(4.90) kg/m² respectively. There were 36 (76.6%) females with a female to male ratio of 1.33:1. The independent t-test comparison of the general characteristics of participants by the group is shown in Table 1. There was no significant difference in both the age distribution and anthropometric parameters of the two groups of study participants.

Table 1: Comparison of the general characteristics of the participants in the Isometric Resisted Exercise (IRE) only group and the IRE plus Russian Current group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>IRE Group (n=23)</th>
<th>IRERC Group (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x ± S.D</td>
<td>x ± S.D</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>63.43 ± 10.23</td>
<td>59.33 ± 10.73</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.58 ± 0.08</td>
<td>1.61 ± 0.07</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>83.43 ± 11.63</td>
<td>80.63 ± 10.54</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>34.38 ± 4.54</td>
<td>31.18 ± 4.90</td>
</tr>
</tbody>
</table>

Key: BMI = Body Mass Index; IRE = Isometric Resisted Exercise; IRERC = Isometric Resisted Exercise plus Russian Current; * Significance level = p < 0.05.

Repeated measure of Analysis of Variance (ANOVA) was used to compare the effects of IRE only and IRERC on quadriceps angle and joint space width across the three time periods (at baseline, 4th and 8th week) as presented in Tables 2 and 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline 4th Week</th>
<th>8th Week</th>
<th>F-ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Angle (*)</td>
<td>19.04 ± 2.75°</td>
<td>18.89</td>
<td>10.82</td>
<td>0.001*</td>
</tr>
<tr>
<td>JSW (mm)</td>
<td>3.04 ± 1.90</td>
<td>2.96</td>
<td>0.691</td>
<td>0.433</td>
</tr>
</tbody>
</table>

Key: IRE = Isometric Resisted Exercise; Q-Angle = Quadriceps Angle; JSW = Joint Space Width; ° = Degree; mm = Millimeter; * Significance level = p < 0.05.

Superscripts (a, b, c).
For a particular variable, mode means with different superscript are significantly (p < 0.05) different. Mode means with the same superscript are not significantly (p > 0.05) different. In each column, a maximum of three contrasts is possible, when only one contrast is significant, one of the three cell means has no superscript attached. The pair of cell means that is significant has different superscript.

Table 3: Repeated measure ANOVA comparison of the effects of IRE on quadriceps angle and joint space width across the three time periods.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>4th Week</th>
<th>8th Week</th>
<th>F-ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Angle (*)</td>
<td>19.04</td>
<td>19.54</td>
<td>19.04</td>
<td>9.41</td>
<td>0.035*</td>
</tr>
<tr>
<td>JSW (mm)</td>
<td>2.92</td>
<td>3.04</td>
<td>3.17</td>
<td>1.10</td>
<td>0.334</td>
</tr>
</tbody>
</table>

Superscripts (a, b, c).
For a particular variable, mode means with different superscript are significantly (p < 0.05) different. Mode means with the same superscript are not significantly (p > 0.05) different. In each column, a maximum of three contrasts is possible, when only one contrast is significant, one of the three cell means has no superscript attached. The pair of cell means that is significant has different superscript.

Table 4: Independent t-test comparison of quadriceps angle and joint space width between IRE only group and IRERC group in the 4th week and 8th week.

<table>
<thead>
<tr>
<th>Variable</th>
<th>IRE (n=23)</th>
<th>IRERC (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Angle (*)</td>
<td>-0.50</td>
<td>-0.30</td>
</tr>
<tr>
<td>JSW (mm)</td>
<td>0.04</td>
<td>0.13</td>
</tr>
</tbody>
</table>

6th Week

<table>
<thead>
<tr>
<th>Variable</th>
<th>IRE (n=23)</th>
<th>IRERC (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Angle (*)</td>
<td>-1.00</td>
<td>-0.96</td>
</tr>
<tr>
<td>JSW (mm)</td>
<td>-0.09</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Key: IRE = Isometric Resisted Exercise; Q-Angle = Quadriceps Angle; JSW = Joint Space Width; ° = Degree; mm = Millimeter.
5. Discussion

This study was carried out to determine the comparative effects of Isometric Resisted Exercise (IRE) and Russian Current (RC) on Quadriceps angle (Q-angle) and Joint Space Width (JSW) among patients with primary knee osteoarthritis (OA). The mean age of the study participants was 61.30 ± 10.58 years. This age category of participants in this study fell within the age bracket of 40 – 75 years within which knee OA is prevalent [35]. Comparison of the mean ages and anthropometric parameters of the two groups also showed no significant difference. This study showed that participants in the Isometric Resisted Exercise Group (IREG) had a significant reduction in their quadriceps angle. This finding is in agreement with previous studies by Lathinghouse and Trimble [36], and Sarkar et al [37]. They both showed that the use of isometric resisted exercises resulted in a decreased Q-angle. Patients with knee OA usually have a weak quadriceps which may be due to reflex inhibition in response to joint effusion and pain, disuse or limited use, loss of mechanical integrity around the knee joint or impaired proprioception [20]. Due to this weak muscle group – especially the medial part of the quadriceps, the knee’s Q-angle begins to gradually increase resulting in knee joint instability. Isometric resisted exercises, on the other hand, strengthens the quadriceps including the vastus medialis which in turns begins to correct the Q-angle. The within-group comparison of participants in IREG across the three time periods of the study revealed that resisted exercise had a significant effect on quadriceps angle. These findings are consistent with previous reports that demonstrated evidence for the use of resisted exercise protocol [38], [39]. This study also showed that Isometric Resisted Exercise plus Russian Current Group (IRERC) had a significant reduction in their quadriceps angle of participants with knee OA post-treatment. Talbot et al [40], in their study, observed an increase in quadriceps muscle strength following treatment of adults with knee OA with RC which had a positive effect on the quadriceps angle. The within-group comparison of participants in IRERC across the three time periods of the study revealed a significant difference in quadriceps angle. These findings are similar to findings from similar studies [40], [41]. Russian current stimulation of the peripheral muscle causes an increase in the excitability of spinal routes, changes in the cortical activation pattern and improves the recruitment of fast twitch (fatigable) muscle fibers which are responsible for strength [42]. Also, there seem to be some neural adaptations that increase the capacity of voluntary muscle contraction that was impaired in patients with knee OA [43]. However, there was no significant difference in the Joint Space Width (JSW) of participants with primary knee osteoarthritis in both the RE only group and IRERC group post-treatment. This is in agreement with a similar study conducted by Mikesky et al [38]. They concluded that resisted exercise over a period of 30 months did not result in an increment in JSW, rather a progressive joint narrowing continued to occur. Segal et al [44], stated that quadriceps weakness was associated with an increased risk of JSW reduction in women but could not prove if an increase in quadriceps strength, resulted in an improved JSW. Messier et al [28], from their study, stated that the medial JSW narrowed more than the lateral JSW probably due to greater weight-bearing load on this compartment and that both parts of the knee joint still underwent progressive JSW narrowing despite aerobic and resisted exercises. Joint space narrowing often results in pseudo-laxity of the medial collateral ligament, stretching of the lateral collateral ligament, and a genu varus deformity [20]. Reasons for non-increase in JSW following resisted exercises might probably be due to the fact that the degenerative process once initiated cannot be reversed [32]. The between-group comparison of participants in the IREG and IRERC across the three time periods of the study also revealed no significant difference in the quadriceps angle and joint space width. Reasons for Russian Current not having an additional effect on quadriceps angle may probably be due to high levels of discomfort some participants experienced as attempts were made to increase the current intensity because they (participants) had reached neural accommodation. Russian current has been shown to generate a greater discomfort level than other therapeutic electric currents like Low-Frequency Pulse Current (LFPC). A contractive force of 50-60% maximum voluntary contraction (MVC) is needed to bring about an effective change physiologically. However, a study done by Laufer and Elboim [45], suggested that participants could only tolerate a maximum electrically induced contractive force of 30% -38% not enough for the needed physiological changes. Another reason may be due to the quick rate at which muscles fatigue during the application of electrical stimulation. Russian current causes the recruitment of fast glycolytic muscle fibers first before that of the slow oxidative muscle fibers [46]. The implication of this is that muscles tend to fatigue faster than compared to aerobic or endurance exercises. But, resisted exercise also has the same order of muscle recruitment as that of Russian current. However, the difference may be in the time allowed motor units to recover and replace used up Adenosine triphosphate (ATP). Two minutes rest period was allocated in-between resisted exercises while a fifty seconds rest interval was observed during the use of Russian current. The Russian current usually follows a protocol to prevent continuous stimulation of the muscles by using the on: off ratio protocol which is usually 1:5 which means 10 seconds contraction with a 50 seconds rest interval [34]. However, fifty seconds may still be insufficient for the motor units to recover before another round of selective recruitment of muscle fibers via synchronous stimulation [47].

6. Conclusion

The use of isometric resisted exercise (using the Delorme resisted exercise protocol) alone had significant effects on quadriceps angle in patients with primary knee osteoarthritis. However, Russian Current did not show additional effects.

Conflict of Interest: None declared

Funding: None

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References


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