

ASSESSING NUTRITION IN SARCOMA PATIENTS THROUGHOUT THEIR TREATMENT: MALNUTRITION RISK AND DIETARY SHIFTS

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Voorwoord

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Maatschappelijke outreach

Populariserende samenvatting

Kanker en ondervoeding zijn nauw met elkaar verbonden. Veel patiënten verliezen gewicht of spiermassa door de ziekte of behandeling, wat herstel bemoeilijkt en het risico op complicaties verhoogt. Een tijdige en correcte beoordeling van de voedingstoestand is daarom belangrijk, maar klassieke maten zoals gewicht en BMI geven niet altijd een volledig beeld van de lichaamssamenstelling. Zo kunnen patiënten met een normaal of hoog BMI toch te weinig spiermassa hebben. Er is dus nood aan eenvoudige en betrouwbare methoden om spiermassa beter op te volgen.

Hoewel voeding steeds meer aandacht krijgt in de oncologische zorg, wordt spiermassa nog zelden systematisch gemeten in de routinepraktijk. De bovenarmomtrek (mid-upper arm circumference, MUAC) is een snelle, goedkope en niet-invasieve meting die hiervoor geschikt lijkt. Hoewel MUAC wereldwijd gebruikt wordt om ondervoeding op te sporen, is er weinig onderzoek bij volwassen kankerpatiënten. In deze masterproef werd een pilotstudie uitgevoerd bij zes sarcoompatiënten in het UZ Gent tijdens de chemo- of radiotherapie voorafgaand aan hun chirurgie. Gewicht, BMI, alsook bovenarm-, taille- en heupomtrek werden herhaaldelijk gemeten in het ziekenhuis en thuis. Patiënten vulden ook vragenlijsten in over eetgewoonten en veranderingen sinds de diagnose.

De meeste patiënten vertoonden een lichte daling in gewicht en bovenarmomtrek, met grote individuele verschillen. MUAC correleerde sterk met gewicht en BMI, wat de betrouwbaarheid van de meting ondersteunt. Thuismetingen kwamen overeen met ziekenhuismetingen, wat suggereert dat MUAC geschikt is voor zelfmonitoring. Deze resultaten tonen dat MUAC een eenvoudige en haalbare manier is om ondervoeding vroegtijdig op te sporen, zowel in het ziekenhuis als thuis. Daarnaast bleek dat patiënten hun voeding op verschillende manieren aanpassen, vaak om bijwerkingen zoals misselijkheid of smaakveranderingen te verminderen. Diëtisten spelen een belangrijke rol bij informatieverstrekking, maar patiënten zochten daarnaast informatie uit diverse andere bronnen. Het actief aanpassen van voeding geeft hen een gevoel van controle en betrokkenheid bij hun behandeling.

Dit onderzoek toont dat MUAC een veelbelovende, toegankelijke methode is om veranderingen in voedingstoestand en spiermassa bij sarcoompatiënten op te volgen. Grotere studies zijn nodig om duidelijke afkappunten en richtlijnen te ontwikkelen, maar MUAC kan op termijn bijdragen aan een meer systematische en gepersonaliseerde voedingszorg in de oncologie.

Maatschappelijke meerwaarde en impact

Ondervoeding blijft een onderschat probleem bij kankerpatiënten, terwijl de gevolgen voor behandelingstolerantie, herstel en levenskwaliteit groot zijn. Toch wordt de ondervoeding nog onvoldoende systematisch beoordeeld in de oncologische zorg. Sarcoompatiënten vormen daarbij een bijzonder kwetsbare groep: ze ondergaan vaak lange, intensieve therapieën, maar worden zelden opgenomen in bredere nutritionele studies door de zeldzaamheid van hun aandoening.

Deze masterproef toont dat bovenarmomtrek (mid-upper arm circumference, MUAC) een laagdrempelige en bruikbare manier is om voedingstoestand op te volgen, zowel in het ziekenhuis als thuis. De praktische haalbaarheid van deze meting maakt niet alleen vroegdetectie van achteruitgang mogelijk, maar biedt patiënten ook de kans actief betrokken te blijven bij hun eigen zorg via eenvoudige zelfmonitoring.

Ten slotte werpt deze studie licht op de vraag in welke mate sarcoompatiënten voedingsadvies ontvangen, via welke kanalen dit gebeurt en welke veranderingen zij zelf in hun eetpatroon doorvoeren. Zo laat de studie zien hoe eenvoudige, betrouwbare metingen gecombineerd met inzicht in patiëntgedrag kunnen bijdragen aan vroegtijdige opsporing van ondervoeding, versterking van patiënten hun autonomie en een meer systematische, patiëntgerichte voedingszorg in de oncologie.

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Abstract

Introduction: Malnutrition is a frequent yet underrecognised problem in oncology, associated with impaired treatment tolerance, reduced quality of life, and poorer survival. In sarcoma, a rare and heterogeneous group of malignancies, evidence on nutritional status and screening practices remains scarce. Given the absence of standardised tools and practical limitations of body composition analyses, simple anthropometric parameters as mid-upper arm circumference (MUAC) could provide valuable alternatives. This pilot study aimed to explore malnutrition risk and post-diagnostic dietary changes in sarcoma patients undergoing neoadjuvant therapy, while evaluating the feasibility and potential clinical utility of anthropometric measurements for both in-hospital and home-based nutritional monitoring, with a specific focus on MUAC.

Material and methods: A monocentric, prospective mixed-methods cohort study was conducted at Ghent University Hospital. Newly diagnosed sarcoma patients scheduled for neoadjuvant chemotherapy or radiotherapy were followed from diagnosis until surgery. Anthropometric measurements (weight, BMI, MUAC, waist, and hip circumference) were performed at three hospital visits and on a weekly basis at home. Dietary changes were assessed through questionnaires. Malnutrition was diagnosed according to the GLIM criteria. Associations between MUAC and other anthropometric parameters were analysed using linear mixed models, and agreement between hospital- and home-based measurements was evaluated using Bland-Altman analysis. Multiple-choice data from the questionnaires were analysed quantitatively using descriptive statistics, and open-ended responses qualitatively using thematic analysis.

Results: Across the six patients, modest mean decreases in BMI (-1.3%) and MUAC (-1.5%) were observed, with substantial interpatient variability. MUAC was significantly associated with BMI ($p = 0.001$) and weight ($p < 0.001$), supporting its relevance as a marker of body composition. Agreement between hospital and home MUAC measurements was strong, indicating feasibility of home-based nutritional monitoring. One patient met the GLIM criteria for malnutrition at all timepoints. Reported dietary changes after diagnosis were heterogeneous, showing no consistent trends across patients.

Conclusion: This mixed-methods pilot study provides preliminary evidence that MUAC is a simple, reliable, and inexpensive tool for assessing and monitoring nutritional status in sarcoma care. While other anthropometric measurements were also informative, MUAC demonstrated practical utility for both hospital- and home-based monitoring. These findings highlight MUAC's potential role in routine nutritional screening and longitudinal follow-up, while emphasising the need for larger studies to validate its diagnostic value and explore the diverse post-diagnostic dietary changes observed in this rare patient population.

Korte samenvatting

Inleiding: Malnutritie is een veelvoorkomend maar vaak onderkend probleem in de oncologie, geassocieerd met verminderde therapietolerantie, een lagere levenskwaliteit en een slechtere overleving. Bij sarcomen, een zeldzame en heterogene groep maligniteiten, is er weinig bewijs over de nutriestatus en nuttiescreening. Gezien het ontbreken van gestandaardiseerde tools en de praktische beperkingen van lichaamssamenstellingsanalyses, zouden eenvoudige antropometrische parameters zoals de middenbovenarmomtrek (MUAC) waardevolle alternatieven kunnen bieden. Deze pilotstudie had tot doel het risico op malnutritie en post-diagnostische voedingsveranderingen bij sarcoompatiënten die neoadjuvante therapie ondergaan te verkennen, en tegelijkertijd de haalbaarheid en potentiële klinische bruikbaarheid van antropometrische metingen voor zowel ziekenhuis- als thuismonitoring te evalueren, met speciale aandacht voor MUAC.

Methoden: Er werd een monocentrische, prospectieve mixed-methods cohortstudie uitgevoerd in het Universitair Ziekenhuis Gent. Recent gediagnosticeerde sarcoompatiënten die neoadjuvante chemotherapie of radiotherapie zouden ondergaan, werden gevolgd van diagnose tot chirurgie. Antropometrische metingen (gewicht, BMI, MUAC, taille- en heupomtrek) werden uitgevoerd tijdens drie ziekenhuisbezoeken en tijdens wekelijkse thuismetingen. Voedingsveranderingen werden beoordeeld via vragenlijsten. Malnutritie werd gediagnosticeerd volgens de GLIM-criteria. Verbanden tussen MUAC en andere antropometrische parameters werden geanalyseerd met lineaire mixed models, en de overeenstemming tussen ziekenhuis- en thuismetingen werd geëvalueerd met Bland-Altmananalyse. Meerkeuzegegevens uit de vragenlijsten werden kwantitatief geanalyseerd met beschrijvende statistiek, en open antwoorden kwalitatief met thematische analyse.

Resultaten: Bij de zes patiënten werden lichte gemiddelde dalingen in BMI (-1.3%) en MUAC (-1.5%) waargenomen, met aanzienlijke variabiliteit tussen patiënten. MUAC was significant geassocieerd met BMI ($p = 0.001$) en gewicht ($p < 0.001$), wat het belang ervan als marker van lichaamssamenstelling ondersteunt. De overeenstemming tussen ziekenhuis- en thuismetingen van MUAC was sterk, wat de haalbaarheid van thuismonitoring ondersteunt. Eén patiënt voldeed op alle tijdstippen aan de GLIM-criteria voor malnutritie. De gerapporteerde post-diagnostische voedingsveranderingen waren heterogeen, zonder consistente trends tussen patiënten.

Conclusie: Deze mixed-methods pilotstudie biedt voorlopig bewijs dat MUAC een eenvoudige, betrouwbare en goedkope tool is voor het beoordelen en opvolgen van de voedingsstatus bij sarcoompatiënten. Hoewel ook andere antropometrische metingen informatief waren, bleek MUAC praktisch bruikbaar voor zowel ziekenhuis- als thuismonitoring. Deze bevindingen benadrukken het potentiële belang van MUAC in routinematige voedingsscreening en longitudinale opvolging, terwijl verdere studies nodig zijn om de diagnostische waarde te valideren en de diverse post-diagnostische voedingsveranderingen bij deze zeldzame patiëntengroep beter te begrijpen.

Introduction

Definition, prevalence and impact of malnutrition in cancer

Malnutrition (or undernutrition) may be defined as “a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcomes from disease” (1). This concept contains malnutrition due to starvation, as well as malnutrition resulting from disease, with or without inflammation. The European Society for Clinical Nutrition and Metabolism (ESPEN) has constructed guidelines on malnutrition definitions, based on their aetiology (figure 1) (1).

Disease-related malnutrition (DRM) with inflammation occurs in diseases that cause a clear inflammatory response, which results in anorexia and tissue breakdown, resulting in weight loss. The ESPEN guidelines recognise both an acute and a chronic subtype (1).

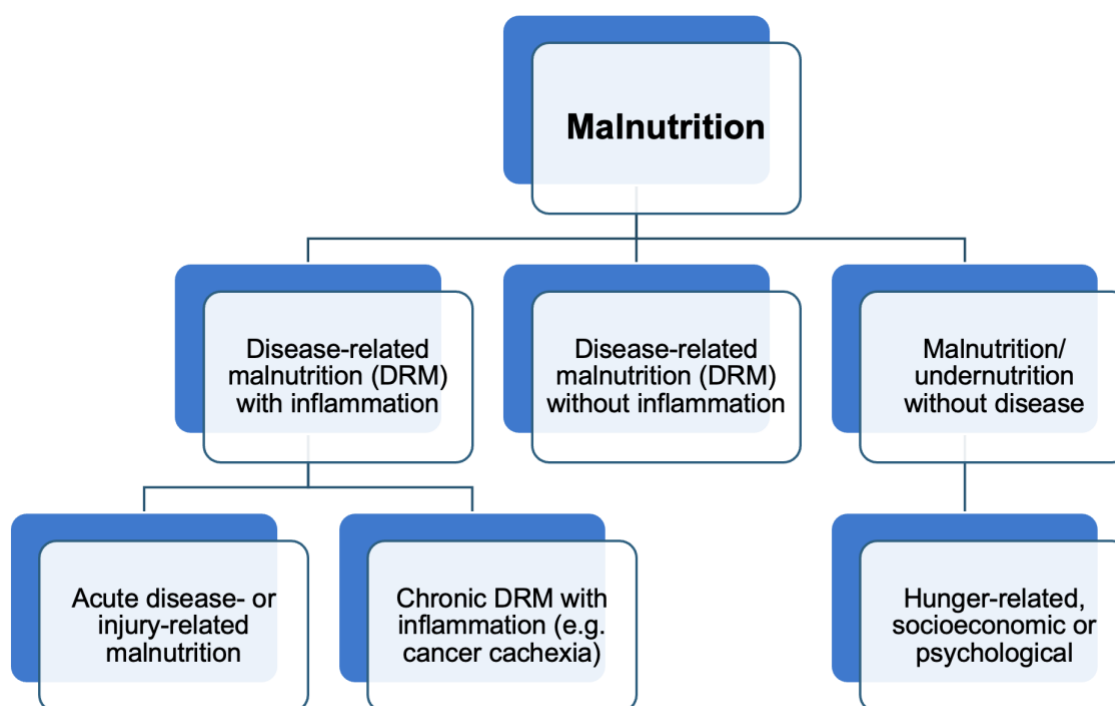


Figure 1 - ESPEN classification of malnutrition. This figure is adapted from the original figure by Cederholm et al. (1).

Acute disease- or injury-related malnutrition typically arises after trauma, major surgery or acute illness, because of a high release of cytokines, catecholamines and corticosteroids, long immobilisation and impaired food intake. In cancer patients, chronic DRM with inflammation, also referred to as cachexia, is most prevalent, whereas it is also frequently observed in chronic obstructive pulmonary disease (COPD), inflammatory bowel diseases, congestive heart failure, chronic kidney disease, etc. It is driven by inflammation, which is usually less pronounced. Chronic DRM with inflammation is diagnosed by the same criteria as for general malnutrition, in combination with underlying disease and an indicator of inflammation such as C-reactive protein (CRP) and/or reduced serum albumin. DRM without

inflammation is caused by alternative aetiological mechanisms than inflammation, e.g. dysphagia caused by neurological diseases, psychiatric conditions, malabsorption caused by intestinal disorders, etc. Malnutrition/undernutrition without disease is the main cause of malnutrition in developing countries. It can be hunger-related, socioeconomic or psychological in origin (1).

Malnutrition is associated with 20-70% of cancers, depending on cancer type, staging and patient age (2-4). It is particularly prevalent in elder patients, and advanced disease is a major risk factor. The wide variation in prevalence may partially result from the use of different diagnostic tools (4). The highest rates reported are in gastroesophageal (49.5%), lung (20.9-45.3%), and head and neck cancers (23.8-48.9%) (4). Gastroesophageal cancers may impair swallowing and digestion, while lung and pancreatic cancer may have a genetic predisposition to cachexia-inducing factors, increasing vulnerability to develop malnutrition (4). A recent Belgian multicentre study using the GLIM criteria, which will be further elaborated below, reported a malnutrition prevalence of 26.3% at diagnosis, which increased to 53.8% and 61.1% at respectively six weeks and four months after the start of therapy (5). While malnutrition prevalence has been well documented in various malignancies, similar evidence in sarcoma patients remains lacking.

In cancer patients, malnutrition has been consistently associated with adverse clinical outcomes. A systematic review applying the GLIM criteria reported reduced overall survival (OS) and relapse-free survival (RFS) in malnourished patients, along with increased rates of postoperative pneumonia, anastomotic leakage, and infectious complications (6). Another meta-analysis using the same criteria found a 90% reduction in OS and a 51% reduction in disease-free survival (DFS) among malnourished cancer patients (7). Furthermore, malnutrition was associated with surgical-site infections, immunosuppression, nosocomial infections, prolonged hospitalisation and elevated healthcare costs (3, 4, 8-10). It is also a treatment-limiting factor in radiotherapy, contributing to reduced treatment intensity, lower quality of life and poorer therapy outcomes (4). Malnourished patients receiving systemic oncological treatments were at a higher risk of developing treatment-related toxicity, making malnutrition one of the major causes of poor therapy tolerance (4).

In addition to clinical outcomes, malnutrition also affects non-clinical outcomes. It has been associated with psychosocial stress, decreased functionality, and a lower quality of life (3, 4, 10). A multicentre study in patients with head and neck or oesophageal cancer showed that poor nutritional status was associated with a lower patient satisfaction regarding overall medical care, physician relationships, communication, and shared decision-making (11).

Aetiology and risk factors of malnutrition in cancer

There are various causes for the development of malnutrition and metabolic alterations in cancer patients (2). The aetiological factors can relate to the tumour, the cancer treatment, such as radiotherapy, chemotherapy and immunotherapy, and/or the dietary changes after cancer diagnosis (2, 12). Reduced caloric intake and/or uptake and systemic inflammation are the two main pathophysiological mechanisms that respectively cause starvation-type and inflammation-type malnutrition or cachexia in cancer (2). In conformity with the ESPEN guidelines on malnutrition definition, the starvation-type and inflammation-type malnutrition respectively correspond to DRM without and with inflammation (1).

Inadequate caloric intake/uptake in cancer patients may result from decreased appetite, due to anorexia, nausea and alterations in smell and taste, or from difficulties with eating, due to dysphagia, vomiting and abdominal pain. Additional causes include impaired gastrointestinal motility, digestion and/or absorption (e.g. mucositis, diarrhoea and stenosis), and a reduced capacity to utilise nutrients, (e.g. hypothyroidism) (2). These mechanisms can stem from the local tumour effect and/or treatment side effects. Dietary changes after cancer diagnosis may also contribute to insufficient intake, and thus to starvation-type malnutrition. However, the latter has been studied much less than the other causes, representing a research gap (12). A systematic review by Aldossari et al. (13), regarding the dietary changes after cancer diagnosis, showed a small overall improvement in dietary intake, however the findings remain inconsistent with unclear clinical consequences.

Systemic inflammation, the second pathophysiological mechanism, is caused by inflammatory and immune cells in the tumour microenvironment and proinflammatory mediators produced by cancer cells. Accordingly, inflammation is described as one of the “hallmarks of cancer” by Hanahan and Weinberg (14). Moreover, infections and tissue damage due to tumour invasion, wounds or treatment interventions contribute further to the systemic inflammation (2).

Although both starvation-type and inflammation-type malnutrition occur in cancer, their metabolic effects and tissue loss differ significantly (2). In starvation-type malnutrition, negative energy balance leads to the breakdown of fat and protein stores to support the basal metabolism important for maintaining vital organ functions and homeostasis. Adaptive metabolic responses include increased autophagy, suppression of anabolic pathways to decrease ATP consumption, and hepatic ketogenesis to spare protein stores from gluconeogenesis by using ketones as fuel instead of glucose (2). By contrast, in inflammation-type malnutrition the protein-sparing adaptations are absent. Instead, systemic inflammation promotes fat and muscle protein breakdown (muscle wasting), anorexia and fatigue, hepatic synthesis of acute-phase proteins, and catabolic endocrine derangements such as insulin resistance (15). Hence, the protein and muscle loss is much higher in inflammatory malnutrition (2). Sarcopenia, defined as low muscle mass in combination with reduced muscle function, is thus frequently associated with cancer cachexia (2, 16).

Risk factors for malnutrition in cancer patients logically reflect its different causes. Thus, previous or current chemotherapy and radiotherapy are independently associated with an increased risk of malnutrition (17). Furthermore, tumour stage and site are also important, with more advanced or metastatic cancer or cancer of the aerodigestive tract showing a higher risk of malnutrition compared to, for example, breast or prostate cancer (17, 18). Other key risk factors for cancer-related malnutrition are older age and unintentional weight loss (19). Kiss et al. (18) found that slow walking pace, multimorbidity, inflammation and low serum 25-hydroxy vitamin D were more frequently associated with low muscle mass, regardless of cancer status. Higher prevalence of malnutrition was also associated with slow walking pace and low protein intake. Specifically for sarcopenia, higher prevalence was seen in the presence of multimorbidity (18). This variety of risk factors highlight the importance of a holistic view on the patient when assessing malnutrition risk.

Screening, assessment and diagnosis of malnutrition in cancer

Cancer patients are clearly at high risk of malnutrition with all its negative prognostic implications (4). Early identification of cancer patients with (high risk of) malnutrition is crucial to mitigate the impact of these adverse outcomes (4, 18). Besides, early nutritional intervention has been shown to improve the quality of life (20). Unfortunately, malnutrition remains widely underdiagnosed, and its severity often underestimated, leaving many patients untreated (2). Namely, expertise in nutrition is often limited due to its underrepresentation in the medical education (2). Nevertheless, international guidelines, such as those from ESPEN, strongly recommend systematic screening of cancer patients for malnutrition, ideally at diagnosis and regularly throughout treatment (1, 20). When the screening, which may be performed by non-nutritionists, shows (a risk of) malnutrition, a more in-depth nutritional assessment by a nutritional expert is required to diagnose the malnutrition and identify the aetiological factors (2, 20). However, there is a lack of consensus on nutritional assessment tools in clinical setting, and it is clearly not yet common practice (20).

Several nutritional risk screening tools have been developed, however none proves to outperform the others (2, 20). International guidelines recommend screening tools that are efficient, brief, inexpensive and have a high sensitivity and good specificity (1, 21). Screening tools that can be used in cancer care include the Malnutrition Screening Tool (MST) (22), Malnutrition Universal Screening Tool (MUST) (23), Nutritional Risk Screening 2002 (NRS 2002) (24) and patient generated-subjective global assessment (PG-SGA) (25). The MST evaluates food intake and weight loss, whereas the MUST additionally considers body mass index (BMI). The NRS 2002 covers disease effect and age alongside food intake, weight loss, and BMI (2). NRS 2002, MST and MUST are malnutrition risk screening tools, while PG-SGA can also be described as a nutritional assessment tool (26). Thus, PG-SGA is not merely a screening tool, but also includes data on nutritional status and may be used after the others as a bridge to more in-depth nutritional assessment (20).

A comprehensive nutritional assessment is needed to diagnose malnutrition and identify the underlying causes, thereby enabling tailored nutritional intervention (20). Such an assessment covers a broad range of parameters, such as weight loss, body composition, energy and substrate intake, nutrition impact symptoms, functional status, gastrointestinal function, and inflammatory markers (e.g. CRP) (2, 20).

In an attempt to standardise the diagnosis of malnutrition, the Global Leadership Initiative for Malnutrition (GLIM) criteria were established. The 2019 GLIM consensus provides a two-step approach to diagnose and differentiate between starvation-type and disease-related malnutrition (27). The first step consists of nutrition screening by any validated tool, examples of which have been mentioned above.

Table 1 – GLIM criteria.

Phenotypic criteria		Aetiological criteria	
Low BMI (kg/m²)	< 20 (if < 70y) or < 22 (if ≥ 70y) Asia: < 18.5 (if < 70y) or < 20 (if ≥ 70y)	Reduced food intake or assimilation	≤ 50% of ER > 1 week or any reduction for > 2 weeks or any chronic GI condition that adversely impacts food assimilation or absorption
Weight loss (%)	> 5% within past 6 months or > 10% beyond 6 months	Inflammation	Acute disease/injury or chronic disease-related
Reduced muscle mass	Reduced by validated body composition measuring techniques		

Malnutrition is diagnosed when at least one phenotypic and one aetiological criterion are present. Abbreviations: GLIM, Global Leadership Initiative for Malnutrition; BMI, body mass index; ER, energy requirements; GI, gastrointestinal.

The second step, following a positive screening, consists of an assessment based on five criteria: three phenotypic and two aetiological (table 1). The phenotypic criteria consist of unintentional weight loss, low BMI and/or reduced muscle mass, whereas the aetiological criteria are reduced food intake/assimilation and/or disease burden/inflammation. These five criteria were voted the most important in the evaluation of the nutritional status by the majority of the GLIM participants. To confirm a malnutrition diagnosis, at least one phenotypic and one aetiological factor must be fulfilled (27). The severity of the malnutrition is classified based on the phenotypic criterion, distinguishing between moderate and severe malnutrition (appendix 1) (28). Recently, a 5-year update paper reported current insights regarding the implementation and integration of GLIM. An important observation is that the used screening tool in the first step affects the prevalence of malnutrition diagnosed by GLIM (28). Namely, NRS 2002 correlates better with the GLIM criteria for malnutrition among cancer patients than MUST. Furthermore, PG-SGA has a low specificity for the diagnosis of malnutrition, despite being a

sensitive tool. Thus, GLIM diagnosis of malnutrition can be used to confirm a suggested malnutrition by PG-SGA (26).

For the assessment of reduced muscle mass, mid-upper arm circumference (MUAC) can be used as a practical and non-invasive measure. Originally introduced in community-based malnutrition screening programs in low- and middle-income countries, it has long been a cornerstone for identifying malnutrition in children (29, 30). MUAC primarily reflects the muscle reserves of the upper arm, although it also includes subcutaneous fat tissue, and can be influenced by oedema (31). When greater specificity for muscle mass is needed, MUAC can be corrected for triceps skinfold thickness (TSF) using established equations, resulting in measures such as mid-arm muscle circumference (MAMC) or bone-corrected arm muscle area (corrected AMA) (31). However, these derived indices require training in skinfold assessment and access to callipers, which may limit their practicality. Despite these limitations, MUAC continues to be valued in clinical practice due to its rapid application and minimal equipment requirements, contributing to its rising recognition in oncology in recent years.

In cancer patients, MUAC may hold additional clinical relevance. Evidence suggests that low MUAC is associated with poorer functional status, greater frailty, and lower quality of life (32). However, findings regarding survival, mortality, chemotherapy-related toxicity, and postoperative complications remain inconsistent (33). Overall, available studies are heterogeneous, reflecting differences in cancer types, treatments, measurement timing, and cut-off values. Moreover, no validated cut-offs are currently established for adult or oncology populations, limiting comparability across studies. A systematic review on this topic, provided in appendix 2, synthesises these findings in detail.

Once malnutrition has been diagnosed, nutritional intervention aims to stabilise or improve the patient's nutritional status. According to the *ESPEN practical guideline: Clinical Nutrition in cancer*, first-line management includes nutrition counselling (NC), treatment of nutrition-impact symptoms and the use of oral nutritional supplements (ONS) when required. Recommended intake generally ranges between 25-30 kcal/kg/day and above 1.0, ideally up to 1.5 g protein/kg/day (34).

NC, which involves providing individualised advice to patients and their caregivers on modifying or enhancing their diet to increase caloric and protein intake, is the cornerstone of nutritional management. A systematic review found that NC, with or without ONS, leads to the most consistent improvements in weight, BMI, and PG-SGA scores, whereas ONS or tube feeding alone only show modest or inconsistent benefits (35). This highlights that, in practice, NC is the primary effective intervention, while other strategies to actively reverse malnutrition are largely lacking (34, 35).

Sarcoma: diagnosis, treatment and prognosis

Sarcomas are a rare, yet heterogeneous group of malignant tumours arising from mesenchymal tissue, accounting for approximately 1% of all malignancies (36-38). They are typically classified into bone sarcomas and soft tissue sarcomas, with the latter representing 70-80% of all cases (37, 38).

Given their rarity and complexity, both bone and soft tissue sarcomas should be diagnosed and treated in specialised reference centres, which has been shown to improve surgical and oncological outcomes. Biopsies must be performed within, or under the guidance of, such reference centres, as improper technique can lead to contamination of surrounding tissue and compromise definitive treatment (38, 39).

Among bone sarcomas, the most prevalent subtypes are osteosarcoma, Ewing sarcoma and chondrosarcoma (36, 38, 39). Osteosarcoma and Ewing sarcoma are primarily present in adolescence, whereas the incidence of chondrosarcoma increases with age (36, 39). Although Ewing sarcomas predominantly originate in bone, they may also arise in soft tissue (36, 38, 39). Bone sarcomas often present with progressive nocturnal bone pain. Over time, swelling and functional impairment may occur (39). When a bone tumour is suspected on radiography, magnetic resonance imaging (MRI) of the entire compartment and adjacent joints is performed, which may be complemented by computer tomography (CT) (39). Diagnosis requires an open surgical biopsy or a core-needle biopsy under imaging guidance, followed by histological and molecular assessment (39).

Treatment of localised osteosarcoma consists of combinations of preoperative and postoperative chemotherapy and surgical resection. Radiotherapy (RT) is used when complete resection is not feasible. In advanced disease, resection and/or RT of local relapse or distant metastasis should be attempted, as it can be curative. For inoperable metastatic disease, chemotherapy is still the mainstay of treatment (38, 39). This multimodal approach has improved the 5-year survival to over 70% in osteosarcoma patients with localised disease. However, in metastatic disease, only 20% of the patients achieve a 5-year survival despite adequate treatment (38, 40).

In Ewing sarcoma, the standard treatment consists of neoadjuvant chemotherapy, followed by local therapy and subsequent consolidation chemotherapy. Complete surgical resection is associated with the most favourable outcomes. When this is not feasible due to complex local anatomy or when surgery is expected to result in unacceptable morbidity, most often in spinal or axial tumours, definitive RT is used as an alternative. In selected cases, adjuvant RT may also be considered. In a metastatic setting, the same treatment approach is used, although prognosis remains significantly worse. As local therapy has been shown to improve outcomes, it should be attempted whenever possible, particularly in metastatic disease responding to systemic therapy. In localised disease, a 5-year survival of 60-75% can be achieved, whereas it declines to 20-40% in metastatic disease (39).

In chondrosarcoma, treatment is more tailored to the specific subtype. Atypical cartilaginous tumours can be treated with curettage, with or without local adjuvant therapy. Low-grade peripheral chondrosarcomas are surgically resected, ideally with a cuff of normal tissue. A 10-year survival of 89-95% can be expected (41, 42). High-grade chondrosarcomas, as well as all tumours located in the pelvis or axial skeleton should be resected with wide margins. For grade 2 chondrosarcoma a 10-year survival of 58-86% can be achieved, declining to 33-55% in grade 3 chondrosarcoma (41, 42). If limb salvage is not feasible, due to the wide margins required, amputation may be performed. If complete resection is not possible, after incomplete surgery or in palliative care, RT can be considered. The use of chemotherapy is generally limited to the rare dedifferentiated chondrosarcomas and mesenchymal chondrosarcomas. In oligometastatic lung disease, particularly in conventional chondrosarcoma, surgery, RT or ablation can be attempted. In case of widespread metastases, chemotherapy offers a limited benefit (39).

Of soft tissue sarcoma (STS), more than 70 different histological subtypes have been discovered, of which liposarcoma (fatty tissue), leiomyosarcoma (smooth muscle) and undifferentiated pleiomorphic sarcoma are the most common (36-38). STS is most frequently situated in the extremities, particularly the thigh, or in the retroperitoneum (36). It often presents as a slowly enlarging, painless mass (43). While metastases are uncommon at time of diagnosis, they can develop later, depending on histological subtype. Hematogenous metastasis is most common, primarily to the lungs, while lymphatic metastasis is rare. The majority of cases are idiopathic, while some are associated with a genetic predisposition such as Li-Fraumeni syndrome, retinoblastoma or neurofibromatosis type 1 (36). As with bone sarcoma, diagnosis relies on a pretreatment biopsy and (immune)histological analysis. Histology is, along with tumour stage and localisation, one of the main prognostic factors (44). Further molecular testing, such as fluorescence in situ hybridisation (FISH) or reverse transcriptase-polymerase chain reaction, is useful to detect specific genetic alterations per subtype, which are used in targeted therapy (43).

Prognosis varies widely between different subtypes and by disease stage at time of diagnosis. Across all stages, the 5-year survival of STS is approximately 65%. However, patients with metastatic disease have a significantly worse 5-year survival of around 15%, compared to approximately 80% in those with localised disease (45). In localised STS, surgery is the treatment of first choice. Limb-sparing surgery has been shown to offer outcomes comparable to amputation and is therefore preferred if adequate resection margins can be achieved. Radiotherapy is often administered either preoperatively or postoperatively, with timing determined individually based on anticipated complications. Acute wound complications related to impaired wound healing are significantly more common after preoperative RT, whereas postoperative RT is associated with a higher risk of oedema, fibrosis, and joint stiffness (43, 44). Advanced or metastatic STS is primarily treated with systemic therapy. Surgery of isolated metastatic lesions can be attempted if possible, as it has proven to prolong survival, though many patients are not eligible (43, 44). For the majority, first-line treatment consists of anthracycline-based

chemotherapy regimens (doxorubicin and/or ifosfamide). However, response rates and survival outcomes remain poor (38, 43, 44).

Research goal

The primary objective of this pilot study is to investigate the nutritional status of patients with sarcoma from their diagnosis throughout their treatment until the surgical resection of the tumour. The nutritional status will be determined by assessing weight loss, BMI and anthropometric measurements such as mid-upper arm, waist, and hip circumference. These measurements are selected as they are relatively inexpensive and little time-consuming. The focus on sarcomas stems from the fact that these rare cancers are widely underrepresented in research, especially in the field of clinical nutrition. Moreover, sarcomas tend to occur sporadically, without strong associations to lifestyle-related risk factors such as smoking, alcohol consumption or obesity. This makes them a particularly suitable population to study nutritional changes largely independent of pre-existing lifestyle-related influences. The GLIM criteria will be used to diagnose malnutrition, and their practical applicability will be evaluated. If possible, the association between the GLIM diagnosis and the MUAC values will be examined. The results of this study may serve as a basis to advocate for systematic nutritional screening in the oncological practice.

The secondary objective of this study is to investigate dietary changes after cancer diagnosis that may occur and may be associated with malnutrition risk. In addition, the study aims to understand the current nutritional support provided to sarcoma patients and the role of dietitians in their care at UZ Gent.

Finally, this pilot study evaluates the feasibility of repeated anthropometric monitoring throughout the treatment trajectory, both in the hospital and at home. Particular attention will be given to the use of MUAC as simple, patient-friendly measurement to assess its practicality and potential role in early detection of nutritional decline in sarcoma patients.

Material and Methods

Study design

A monocentric, prospective observational cohort study was conducted at the department of Bone and Soft Tissue Sarcoma at Ghent University Hospital (UZ Gent) between March 2025 and October 2025. This study aimed to assess the nutritional status and dietary changes in newly diagnosed sarcoma patients during their neoadjuvant chemotherapy and/or radiotherapy.

Ethical considerations

This study received a positive ethical advice in accordance with the law of 7 May 2004 regarding experiments on the human person. The Medical Ethics Committee of Ghent University (UGent) and Ghent University Hospital (UZ Gent) has reviewed and approved this study on 7 January 2025 (Belgian Registry nr.: B6702024000574). Written informed consent was obtained from all participating patients prior to any study-related procedures.

Study population

The study population was recruited through consultations with dr. Desirée Dorleijn or prof. dr. Gwen Sys, following a histologically confirmed sarcoma diagnosis. Potentially eligible patients received brief verbal information about the study, along with a flyer and an informed consent form. They were asked for permission to be contacted by the master students the following week. If permission was given, patients were called, provided with more detailed information, and a first visit was scheduled, linked to an existing hospital appointment at UZ Gent. During the first visit, the information letter and informed consent form were reviewed together with the patients.

Inclusion criteria:

- Age $\geq$ 18 years
- New histological sarcoma diagnosis
- Scheduled to undergo neoadjuvant chemotherapy and/or radiotherapy

Exclusion criteria:

- Inability to consume food orally (e.g. patients receiving tube feeding)
- Relapsed or recurrent sarcoma
- Patients opting for definitive radiotherapy (without a planned surgical resection)

Measurements

This study used both quantitative and qualitative methods to monitor patients' nutritional status and potential behavioural changes throughout the preoperative treatment.

Anthropometric measurements included height, weight, mid-upper arm circumference (MUAC), waist circumference, and hip circumference.

- **Height** was measured to the nearest 0.1 cm at the start of the study using a stadiometer or a Seca 203 measuring tape. Patients were asked to take off their shoes and attention was paid to an upright posture. If the patient's height was already measured regarding their neoadjuvant treatment, then that number was adopted as the medical team uses the same height measurement tools and method.
- **Weight** was measured to the nearest 0.1 kg with the same type of scale during study visits as at home, using the Tefal PP1400 Premsis digital scale. This way, data from study visits could be compared to the weekly home measurements. Patients were asked to be barefoot and undress to their underwear during the study visits and to preferably be naked at home when measuring their weight. Attention was also paid to an upright posture on the scale.
- **Mid-upper arm circumference (MUAC)** was measured to the nearest 0.1 cm during the study visits as at home. The master's students used a Seca 203 measuring tape during the visits, while the patients received a simple measuring tape to use at home. With the arm in a 90° angle across the trunk, the midpoint between the tip of the acromion and the olecranon ulnae was measured. Thereafter, the arm was extended alongside the body and the circumference at the midpoint of the upper arm was measured. Unless contraindicated (e.g. oedema, injury, or medical device), the non-dominant arm was used.
- **Waist circumference** was measured to the nearest 0.1 cm using the same equipment as for MUAC. By palpation, a midpoint approximately halfway between the lower margin of the twelfth rib and the top of the iliac crest was determined. At this level, the circumference was measured in a horizontal plane.
- **Hip circumference** was measured to the nearest 0.1 cm using the same equipment as for MUAC and waist circumference. Here, a horizontal plane around the widest part of the buttocks was taken for the measurement.

For MUAC, waist and hip circumference, it was important to apply the measuring tape snugly, without compressing the skin.

Questionnaires consisted of two components:

- A validated food frequency questionnaire¹ (FFQ) developed by Sciensano (46) (appendix 3)
- A questionnaire assessing changes since diagnosis in diet, alcohol consumption, smoking behaviour and physical activity (appendix 4)

Timing of the measurements (figure 2):

- **Visit 1:** 1 to 2 weeks post-diagnosis, prior to the initiation of treatment
- **Visit 2:** Mid-treatment; conducted in hospital for patients treated at UZ Gent, or via phone call for patients receiving radiotherapy at a peripheral hospital
 - o *Note: in the latter case, anthropometric measurements were performed by patients at home*
- **Visit 3:** 1 to 2 weeks prior to surgical resection, following the completion of neo-adjuvant treatment
- **Home measurements** were conducted weekly and included weight, MUAC, and, where feasible, waist and hip circumference. Patients were provided with a Tefal PP1400 Premiss digital scale and a simple measuring tape during visit 1, along with detailed verbal and written instructions on how to perform these measurements (appendix 5).

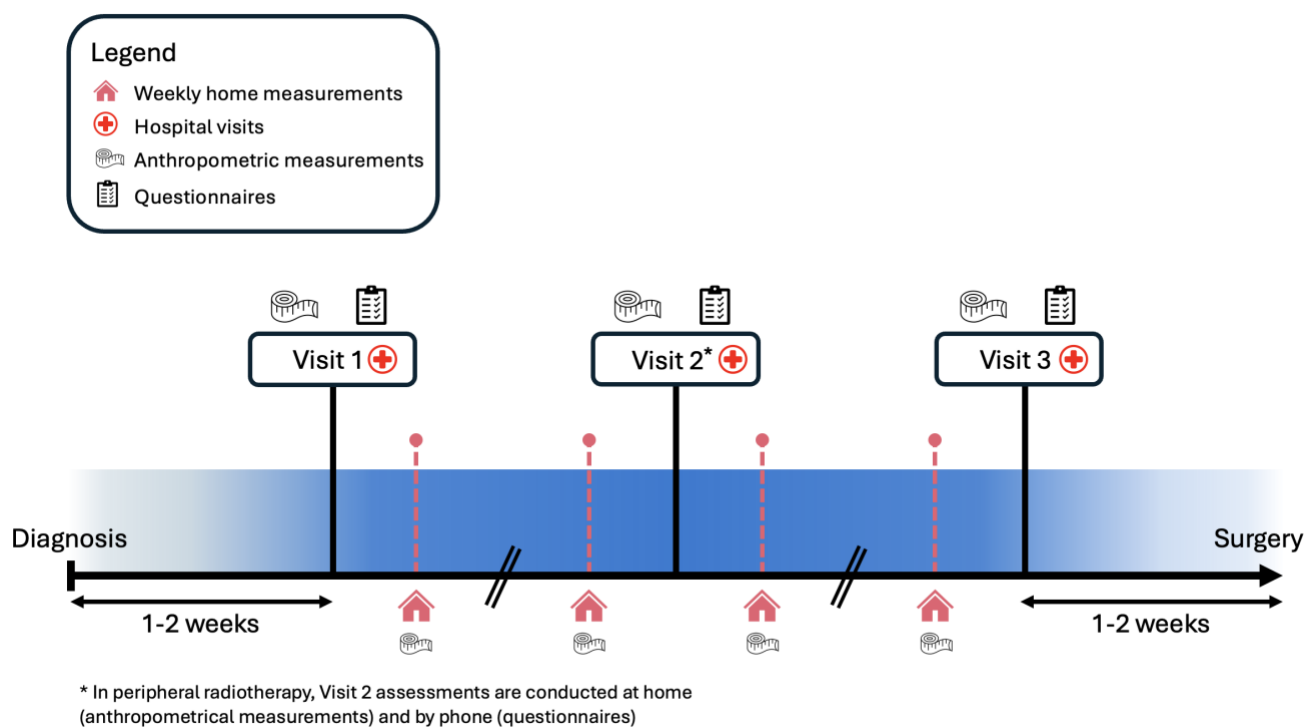


Figure 2 - Timeline measurements.

¹ The FFQ assessed dietary intake over the 12 months before visit 1 and for the intervals between visit 1-2 and visit 2-3; each later FFQ covered only the period since the previous visit.

Data collection

Data collection was performed by the master students, following the *Report of a WHO Expert Consultation on Waist Circumference and Waist–Hip Ratio* (47) and the *Report of a WHO Expert Committee on Physical Status: the Use and Interpretation of Anthropometry* (48) to ensure consistency and accuracy. During each visit, patients completed the two questionnaires together with the students and underwent the anthropometric measurements as described above.

For patients undergoing radiotherapy at a peripheral hospital, visit 2 was conducted via phone. In these cases, anthropometric measurements were performed at home, and the questionnaire responses were collected during the phone call.

Patients were instructed to perform the anthropometric measurements on a weekly basis. These were manually recorded by the patients, if possible, with assistance from a family member, and collected by the students during each hospital visit (appendix 6).

In order to describe the usual nutritional care for sarcoma patients, a brief interview with an oncology dietitian at UZ Gent was conducted, covering the general workflow, the referral process, and the number of patients seen. In addition, patient files were reviewed to identify all sarcoma patients who were undergoing treatment between January 1st and July 30th, 2025.

Data storage

All collected data were pseudonymised and securely stored using REDCap. Identification data were stored separately on a secured drive at UZ Gent, only accessible to authorised research personnel.

Data analysis

In regards to this study's research question a mixed-methods research was performed, combining both quantitative and qualitative data analysis. The statistical software IBM SPSS Statistics 28 was used to perform descriptive data analyses, as well as Linear Mixed Model (LMM) and Bland-Altman analyses. Statistical significance was defined as $p < 0.05$.

LMMs were conducted to examine the effect of BMI, weight, waist and hip circumference on MUAC, taking into account repeated measurements over time within the patients. MUAC was defined as the dependent variable, with BMI, weight, waist and hip circumference as the fixed effects and patient number as the random intercept. The models were estimated using Restricted Maximum Likelihood (REML) method and a variance components covariance structure. The dataset used for the LMMs only included the 3 hospital visits' measurements of the patients. The use of LMMs allows inclusion of

all available data and provides robustness in case of missing values, under the missing-at-random assumption. Before running the LMM, data were screened for outliers through boxplots. Outliers were defined based on the interquartile range (IQR). More specifically, observations were outliers when they were more than 1.5 times the IQR away from the quartiles. Afterwards, model assumptions of normality and homoscedasticity were respectively verified by visual inspection of residual Q-Q plots and scatterplots of residuals versus predicted values.

A Bland-Altman analysis was performed to assess the agreement between the slopes of hospital and home measurements for MUAC, weight, waist and hip circumference. This approach allowed to estimate how well home-based trends correspond to those from the hospital setting. The used dataset consisted of 2 slopes values for each of the 4 parameters and patients. The Bland-Altman variables, namely the mean and the difference of the 2 slopes, were calculated and the assumption of normality of the differences was checked by visual inspection of Q-Q plots. The mean bias and 95% limits of agreement (LoA) were computed as the mean difference and the mean difference ± 1.96 times the standard deviation (SD) of the differences, respectively. The agreement was interpreted by visual inspection of the Bland-Altman plot with reference lines for the mean bias, the upper and lower LoA, and the zero line for perfect agreement.

Because no validated MUAC cut-off values are currently available within the GLIM framework, either for absolute thresholds or for longitudinal decline, thresholds proposed by Costa-Pereira et al. were used. Rounded cut-off points for MUAC were set at 28 cm for men and 25 cm for women, and for very low MUAC at 26 cm and 23 cm, respectively. Furthermore, BMI-adjusted correction factors of -3 cm (men) and -2 cm (women) for BMI 25-29.9 kg/m², -7 cm (men) and -6 cm (women) for BMI 30-39.9 kg/m², and -10 cm (men) and -9 cm (women) for BMI ≥ 40 kg/m² were applied (31). To our knowledge, no slope-based MUAC thresholds have been validated to indicate clinically relevant change over time, in contrast to weight, where percentage loss over a defined period (e.g., $\geq 5\%$ in 6 months) is routinely applied in malnutrition diagnosis. This limits the ability to interpret longitudinal MUAC changes, as malnutrition can only be established based on absolute cut-offs rather than temporal decline. Moreover, because MUAC measurements are rarely available before diagnosis, pre-treatment muscle loss often remains undetected, potentially underestimating the true burden of cancer-related malnutrition.

Data from the FFQ and the multiple-choice items of the questionnaire dietary changes (appendix 3 and 4) were analysed quantitatively using descriptive statistics. Open-ended responses from the latter questionnaire were analysed qualitatively using a thematic content analysis to identify recurring patterns and contextual insights.

Use of AI

The use of generative artificial intelligence (AI) tools was discussed prior to the start of this master's thesis. Responsible use of AI was approved, provided that its application was transparent. AI tools were employed for several supportive purposes. Specifically, language models were used to review style, grammar and clarity of written sections, while tools such as Elicit assisted in literature search and synthesis. Additionally, one AI-generated image was used in the design of recruitment flyers and posters.

Results

Study sample

During the recruitment period, 11 patients were considered eligible based on the inclusion and exclusion criteria. Of these, 3 patients declined participation and 2 were unable to participate due to practical constraints, resulting in a total of 6 patients being included in the study. Their baseline characteristics are presented in table 2.

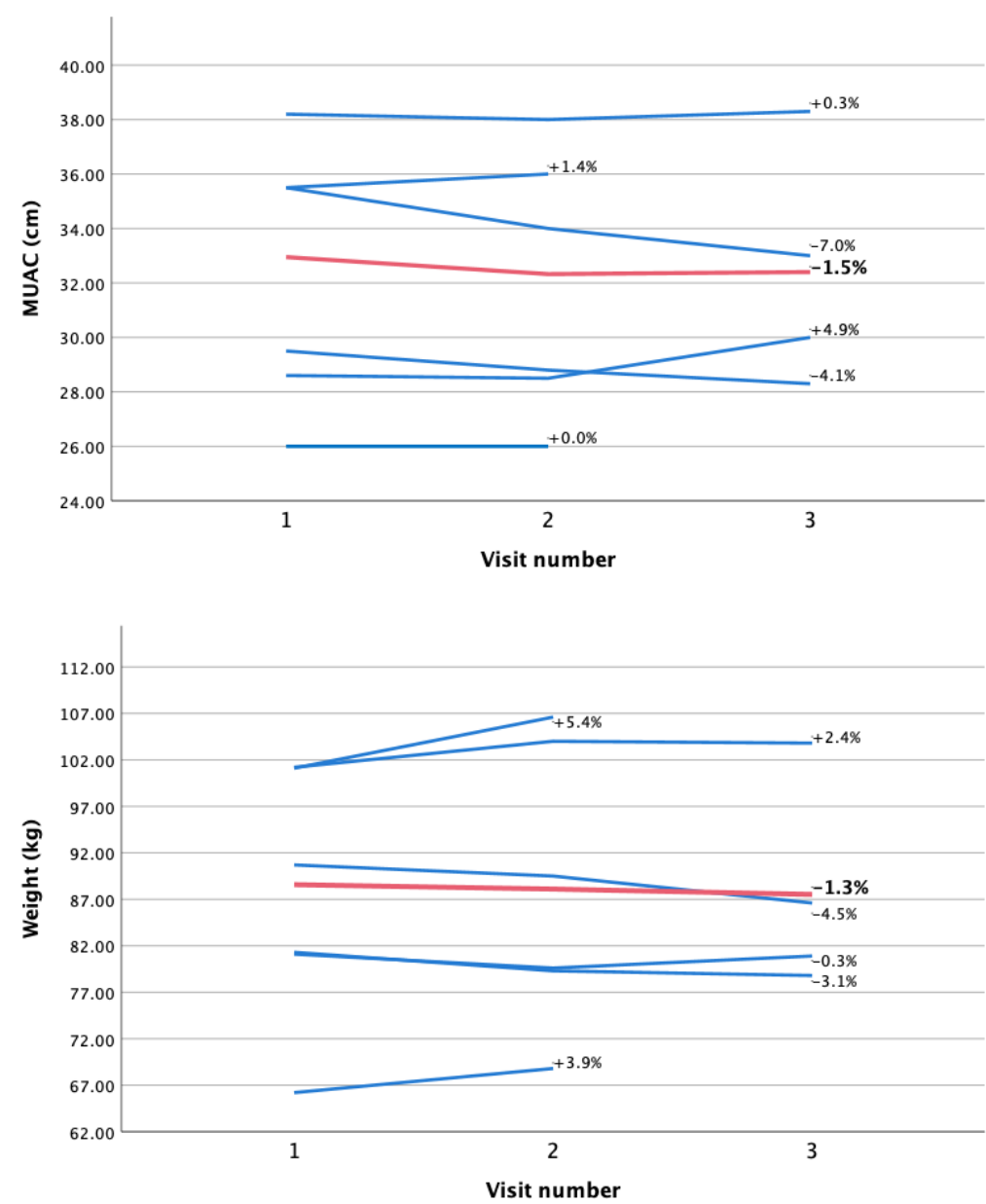
The full follow-up period was completed by 4 patients, while 2 were followed up until the second hospital visit due to the timing of data collection. Owing to differences in individual treatment plans, the total follow-up time varied between participants, with a mean of 10.4 weeks for the entire cohort and 11.8 weeks among those with complete data. On average, participants performed 8.8 weekly home measurements, increasing to 10.3 for patients with complete data. At baseline, the mean BMI was 27.9 ± 4.1 kg/m² and the mean waist-to-hip ratio (WHR) was 0.91 ± 0.08 , both above the WHO reference values, indicating that participants were, on average, overweight and at increased cardiometabolic risk (47, 49).

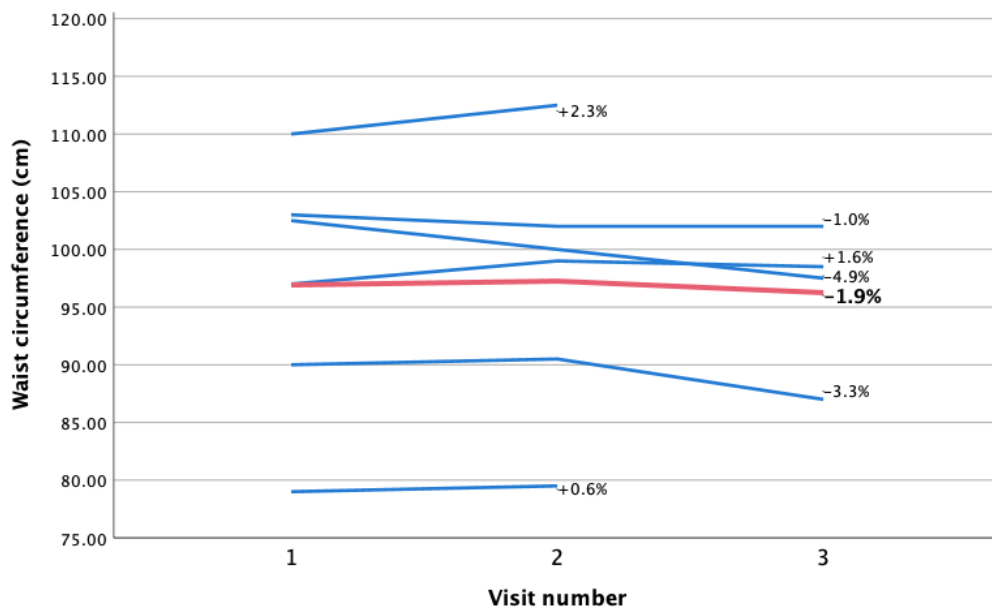
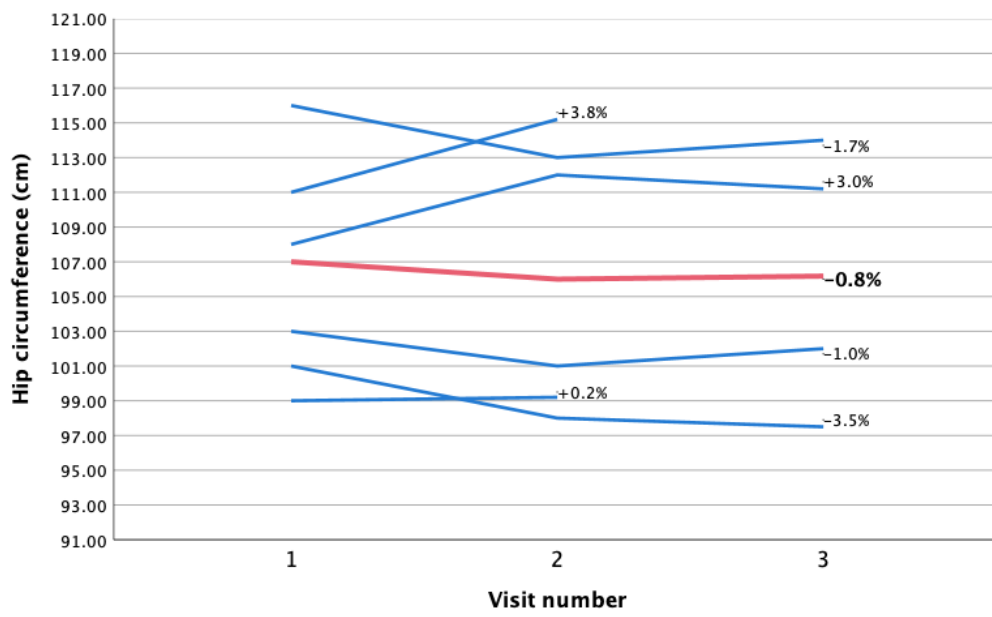
Table 2 - Baseline characteristics.

Sample characteristics	Study sample (n=6)
Demographics	
Age, years (mean $\pm$ SD)	45.5 $\pm$ 17.5
Gender	
Male, n (%)	4 (66.7)
Female, n (%)	2 (33.3)
Sarcoma diagnosis	
Osteosarcoma, n (%)	2 (33.3)
Myxofibrosarcoma, n (%)	1 (16.7)
Ewing sarcoma, n (%)	1 (16.7)
Myxoid liposarcoma, n (%)	1 (16.7)
Leiomyosarcoma, n (%)	1 (16.7)
Type of neoadjuvant treatment	
Chemotherapy, n (%)	5 (83.3)
Radiotherapy, n (%)	1 (16.7)
Anthropometrics	
Height, cm (mean $\pm$ SD)	176.6 $\pm$ 8.0
Weight, kg (mean $\pm$ SD)	86.9 $\pm$ 13.5
BMI, kg/m ² (mean $\pm$ SD)	27.9 $\pm$ 4.1
MUAC, cm (mean $\pm$ SD)	32.1 $\pm$ 4.8
Hip circumference, cm (mean $\pm$ SD)	106.3 $\pm$ 6.5
Waist circumference, cm (mean $\pm$ SD)	96.9 $\pm$ 11.0
Waist-to-hip ratio (mean $\pm$ SD)	0.91 $\pm$ 0.08

Abbreviations: SD, standard deviation; BMI, body mass index; MUAC, mid-upper arm circumference.

Anthropometric measurements over time





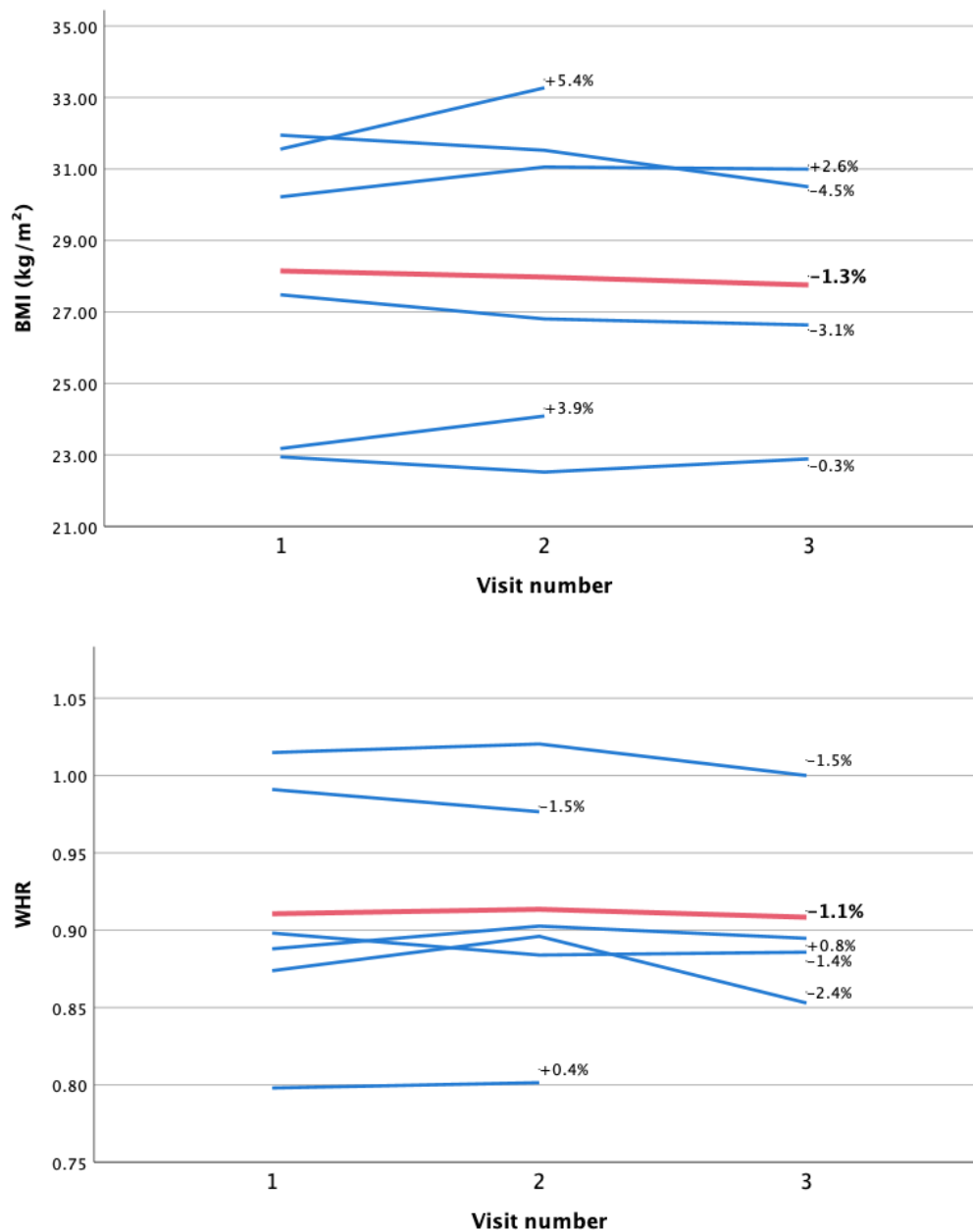


Figure 3 - Evolution of anthropometric measurements at each hospital visit. Each blue line represents one patient, with the pink line indicating the group mean. Abbreviations: BMI, body mass index; MUAC, mid-upper arm circumference; WHR, waist-to-hip ratio.

Figure 3 illustrates the individual trajectories and mean trends for the six anthropometric measurements across the hospital visits. Overall, the graphs demonstrate a substantial interpatient variability. Despite this variation, the mean trends indicate a modest overall reduction in body dimensions between visit 1 and visit 3.

The mean weight and BMI both showed small decreases of -1.3%, with an initial slight rise between visit 1 and 2, followed by a decline. MUAC displayed a comparable non-linear pattern, resulting in an overall mean decrease of -1.5%.

Among the circumferences, waist circumference showed the most pronounced change, with a reduction of 1.9%, while hip circumference remained more stable (-0.8%). The waist-to-hip ratio remained nearly constant at a value around 0.90 across all visits, resulting in a minimal change of -1.1%, indicating proportionally similar changes in waist and hip circumference. More detailed descriptive results, including mean values for visits 2 and 3 and mean changes, are presented in appendix 7.

Associations between MUAC and other anthropometric measurements

Table 3 – Results of the linear mixed models for the association between MUAC and other anthropometric measurements.

Parameter	Estimate	95% CI	Standard error	P-value
BMI	0.88	0.43 – 1.32	0.20	0.001
Weight	0.31	0.21 – 0.41	0.04	<0.001
Hip circumference	0.31	0.07 – 0.54	0.11	0.015
Waist circumference	0.19	-0.07 – 0.44	0.11	0.132

MUAC was used as the dependent variable. Abbreviations: BMI, body mass index; CI, confidence interval.

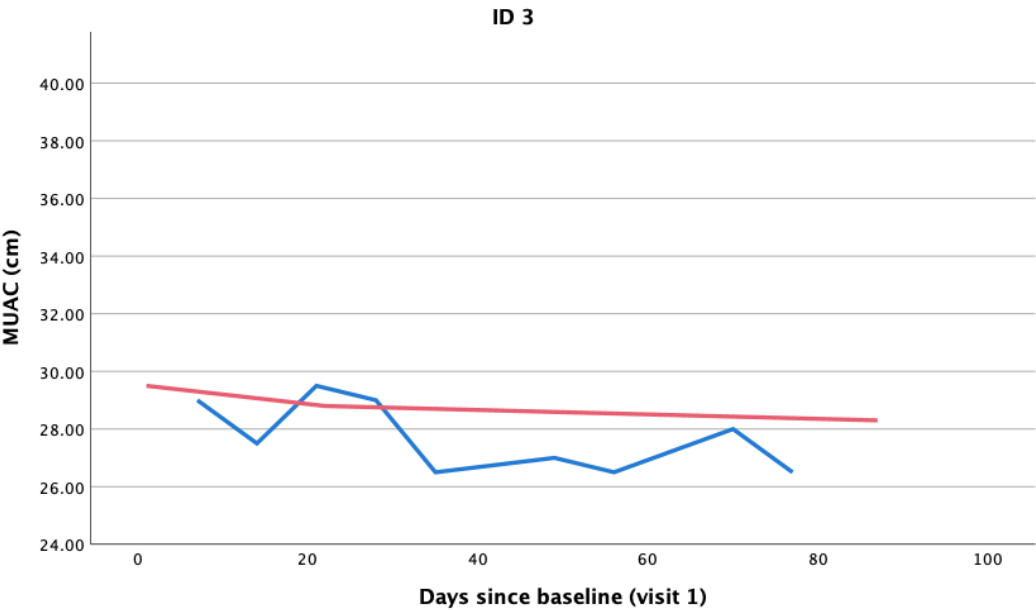
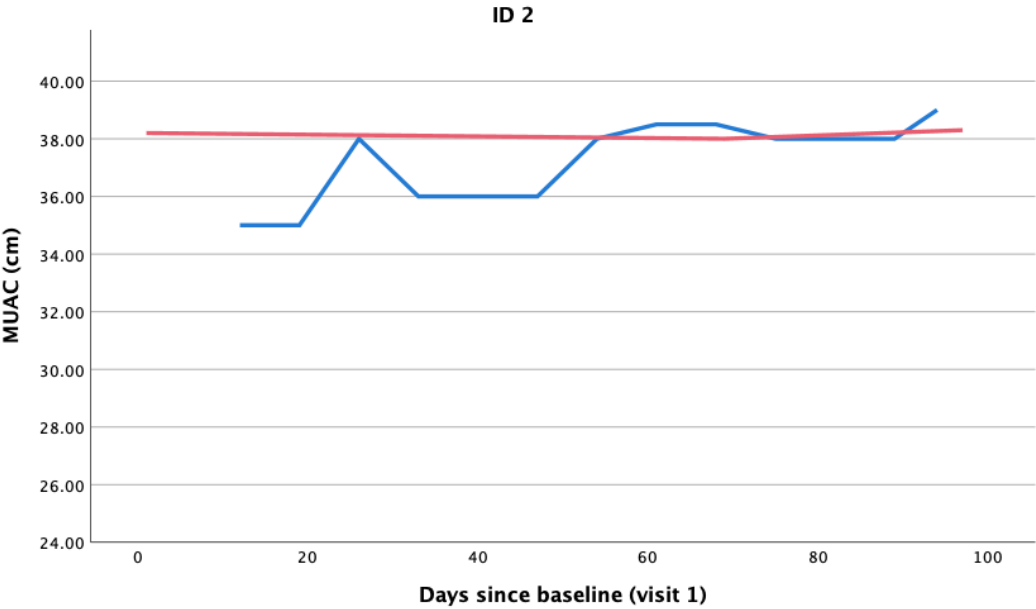
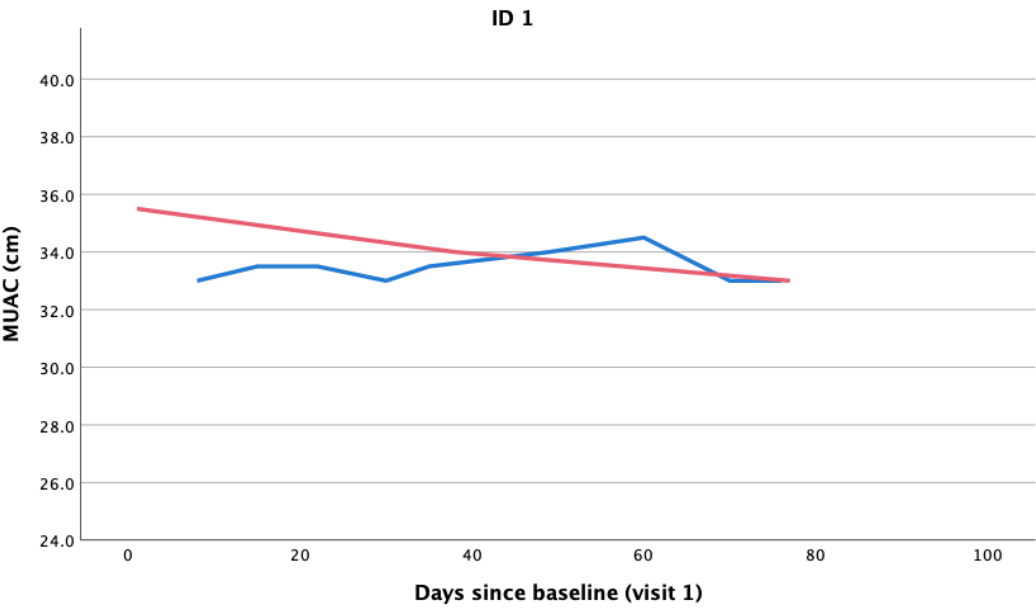
Prior to running the LMM analyses, data were screened for outliers using boxplots. No outliers were observed for MUAC, BMI, waist, or hip circumference (appendix 8a). Of the 18 planned observations, only 16 were available for analysis due to 2 patients missing their third measurement point. Under the assumption of missing at random (MAR), LMMs are able to handle missing data. Therefore the missing observations were excluded listwise and no imputation was needed.

As shown in table 3, the LMM with MUAC as dependent variable, BMI as fixed effect, and patient number as random intercept, demonstrated a significant association between BMI and MUAC ($p = 0.001$; full SPSS output in appendix 8b). This indicates that, for every 1-point increase in BMI, the mean MUAC increases by approximately 0.88 cm. Similar LMMs with weight and hip circumference as fixed effects also showed significant associations with MUAC ($p = <0.001$ and $p = 0.015$, respectively), corresponding to an estimated increase in MUAC of about 0.31cm per 1-point increase in weight or hip circumference.

For these 3 LMMs, residual diagnostics did not reveal notable deviations from normality or homoscedasticity. The residual Q-Q plots, scatterplots of residuals versus predicted values, and boxplots of the residuals are presented in appendix 8c, 8d, and 8e, respectively.

The LMM with waist circumference as fixed effect did not reach statistical significance ($p = 0.132$). Residual diagnostics indicated moderate non-normality and heteroscedasticity, and the residuals contained several outliers and extreme values. Therefore, model assumptions were not met, and results should be interpreted with particular caution.

Home measurements



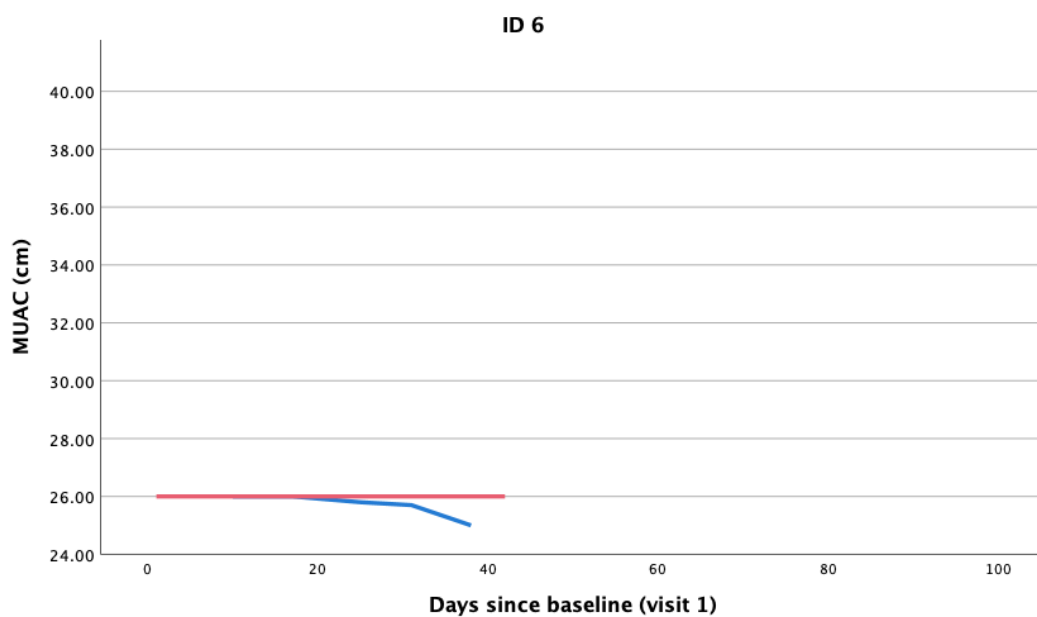
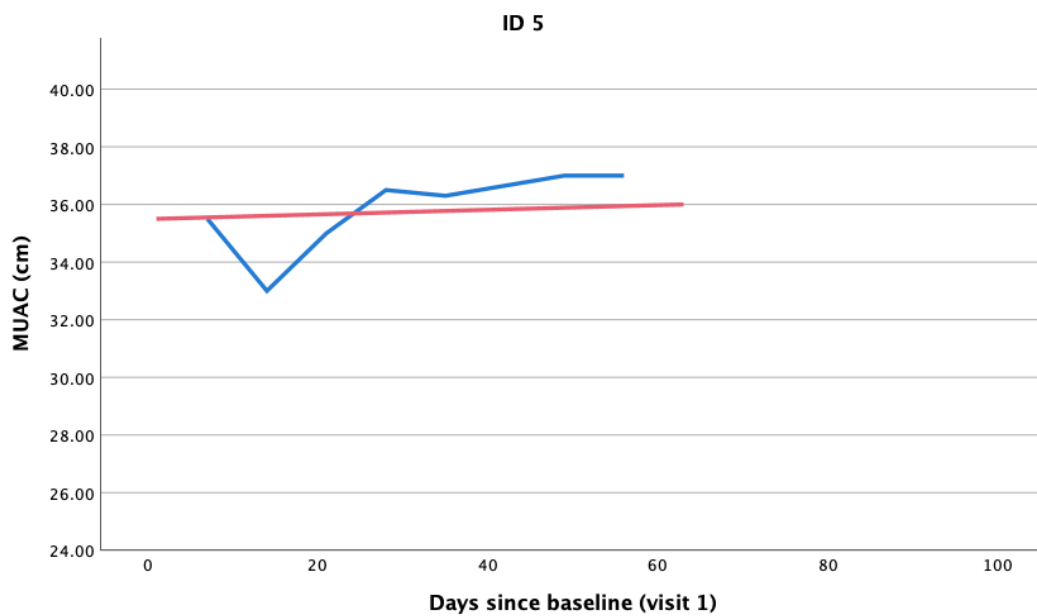
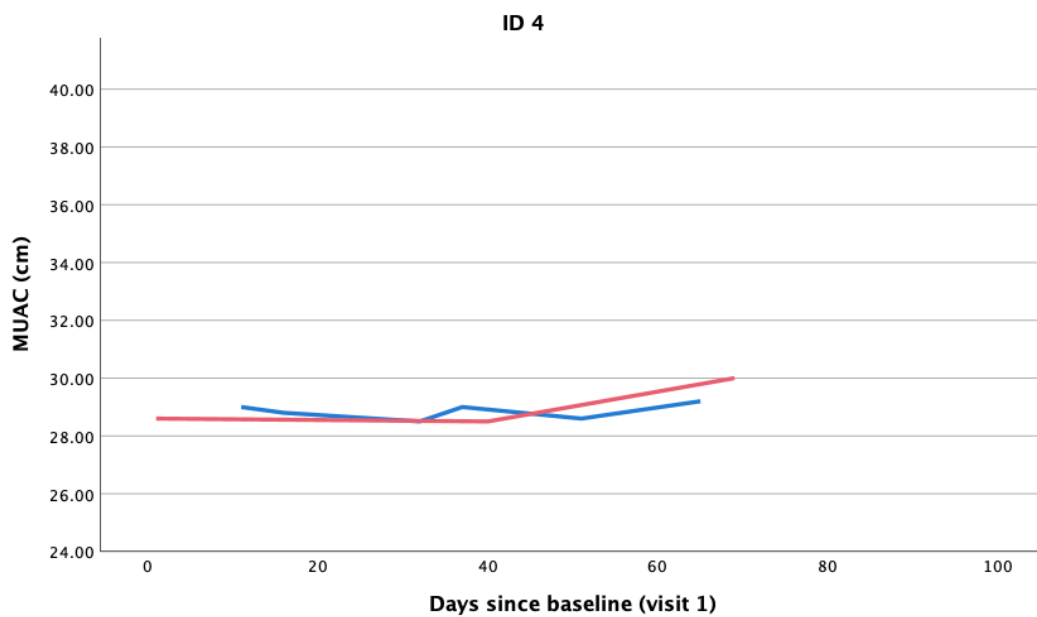


Figure 4 – MUAC trajectories (hospital vs. home). Individual trajectories (ID 1-6) of MUAC are shown; hospital visits in pink and home measurements in blue. Time is expressed in days since baseline (hospital visit 1). Abbreviations: MUAC, mid-upper arm circumference.

Figure 4 illustrates the individual MUAC trajectories obtained from home (blue line) and hospital (pink line) measurements. Although visual inspection shows some within-patient variation, the overall trends between both settings appear largely comparable. The corresponding graphs for weight, hip, and waist circumference are provided in appendix 9a, 9b and 9c, respectively.

Table 4 - Agreement between hospital and home measurements: Bland-Altman Analysis.

Parameter	Mean bias	95% LoA	Agreement
MUAC	-0.010 ± 0.037	-0.082 to 0.061	Good
Weight	-0.000 ± 0.029	-0.057 to 0.056	Strong
Hip circumference	0.023 ± 0.060	-0.096 to 0.141	Moderate
Waist circumference	-0.031 ± 0.041	-0.111 to 0.049	Moderate

Slope differences between hospital and home measurements (cm/day for MUAC, hip and waist circumference; kg/day for weight), presented as mean bias ± standard deviation. A negative or positive mean bias indicates that the home or hospital slope, respectively, is steeper. Agreement between the measurement settings is further indicated by the width of the limits of agreement (LoA), with a narrower LoA reflecting stronger agreement. Abbreviations: LoA, limits of agreement.

As seen in table 4, for MUAC the mean bias between hospital and home slopes (hospital - home) was -0.010 cm/day (SD = 0.037), indicating that home slopes were on average slightly steeper than hospital slopes. The mean bias was close to 0, and the 95% LoA were relatively narrow (-0.082 to 0.061), suggesting good overall agreement. Upon visual inspection of the Bland–Altman plot, all differences laid within the LoA and appeared randomly distributed around the mean bias, with no apparent trend across the range of average slopes, suggesting the absence of both systematic and proportional bias, respectively (appendix 10).

Comparable results were observed for weight, with a mean bias after rounding equal to 0 (-0.000) and narrower LoA (-0.057 to 0.056), suggesting even stronger agreement between the measurement settings. Bland-Altman plots for hip and waist circumference showed slightly wider variability between home and hospital slopes (table 4). Visual inspection of Q-Q plots indicated no major deviations from normality for the differences between hospital and home slopes (appendix 11).

Diagnosis of malnutrition

Table 5 - Presence of GLIM-defined malnutrition per patient in each visit.

Patient	Visit 1	Visit 2	Visit 3
1	×	×	×
2	×	×	×
3	✓	✓	✓
4	×	×	×
5	×	×	*
6	×	×	*

✓ = meets GLIM criteria for malnutrition. × = does not meet the criteria. * = visit not performed.

Table 5 shows the presence of malnutrition according to the GLIM criteria for each patient across the 3 visits. One patient met the GLIM criteria at all time points, whereas the remaining patients did not fulfil the criteria at any time. This patient already met the GLIM criteria at baseline, corresponding to moderate malnutrition, and showed very low MUAC values at visits 2 and 3, corresponding to severe malnutrition (appendix 1). For patients 5 and 6, as described earlier, visit 3 data were not available.

As seen in table 1, cancer patients, by definition, have a fulfilled aetiological criterion due to the inflammation associated with malignancies. The diagnosis of malnutrition in this population therefore depends on the fulfilment of the phenotypical criterion. The only patient in this study with malnutrition was diagnosed with reduced muscle mass based on MUAC cut off values. Patient 1 almost met the criteria with a weight loss within 6 months of 4.5%.

Post-diagnostic dietary changes

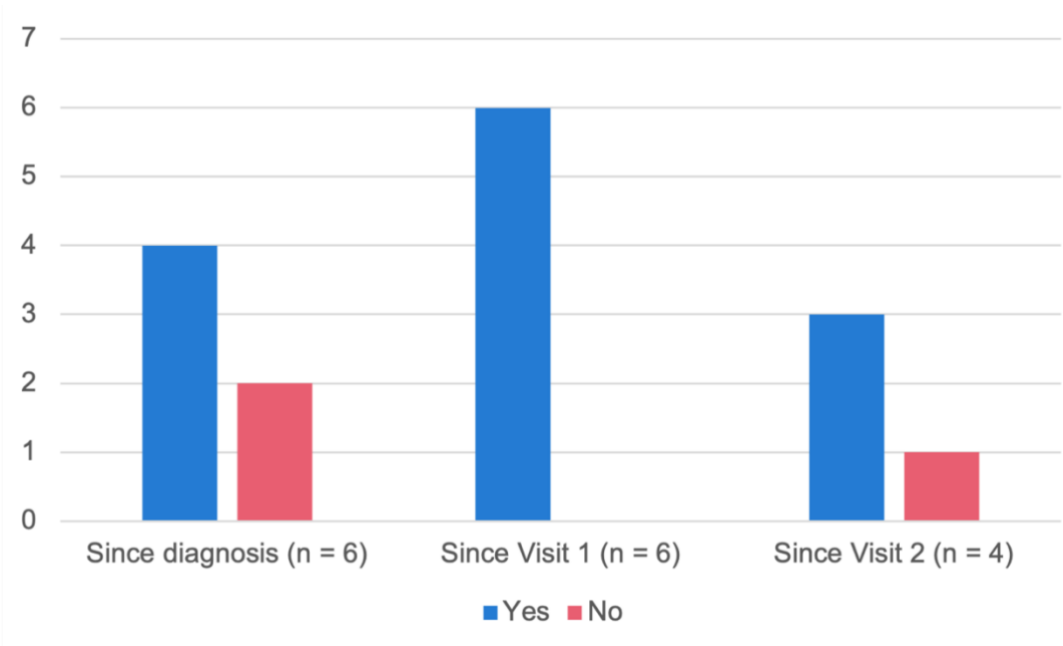
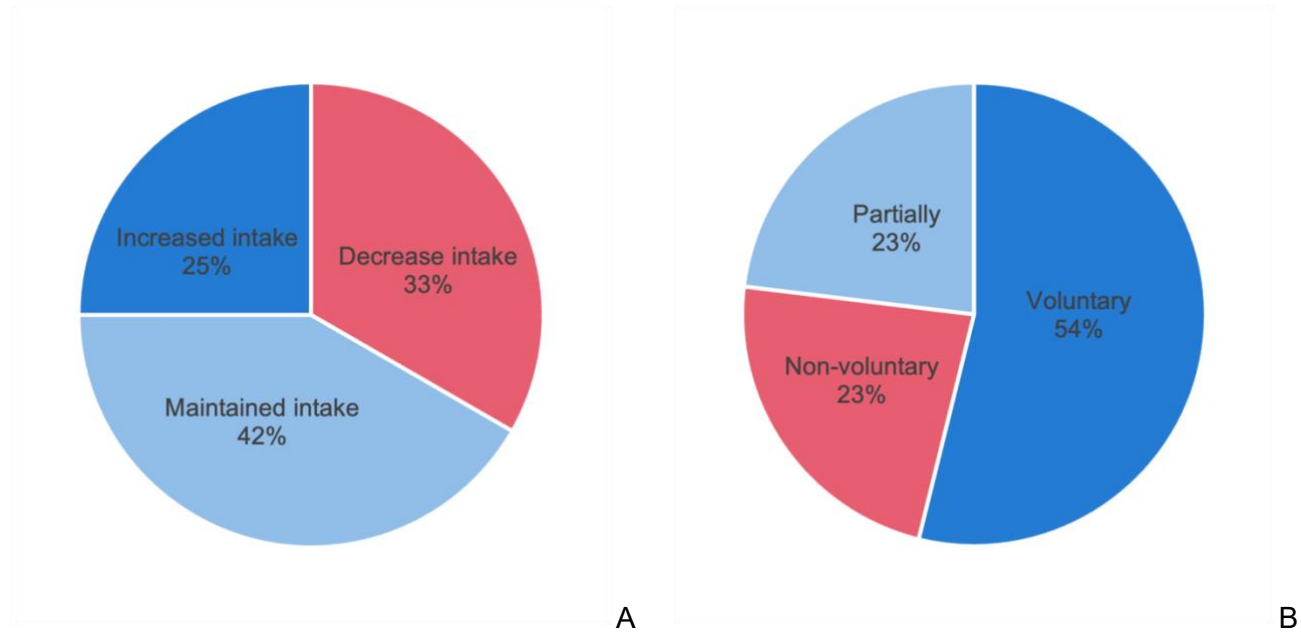


Figure 5 - Reported dietary changes over time. 'Yes' indicates that a change in diet was reported, and 'No' indicates that no change was reported.

Figure 5 illustrates whether patients reported dietary changes following diagnosis, since the first and/or the second visit. Notably, all patients indicated having modified their diet after treatment initiation. Visit 1 corresponded to the start of treatment and visit 2 occurred halfway through the treatment period.



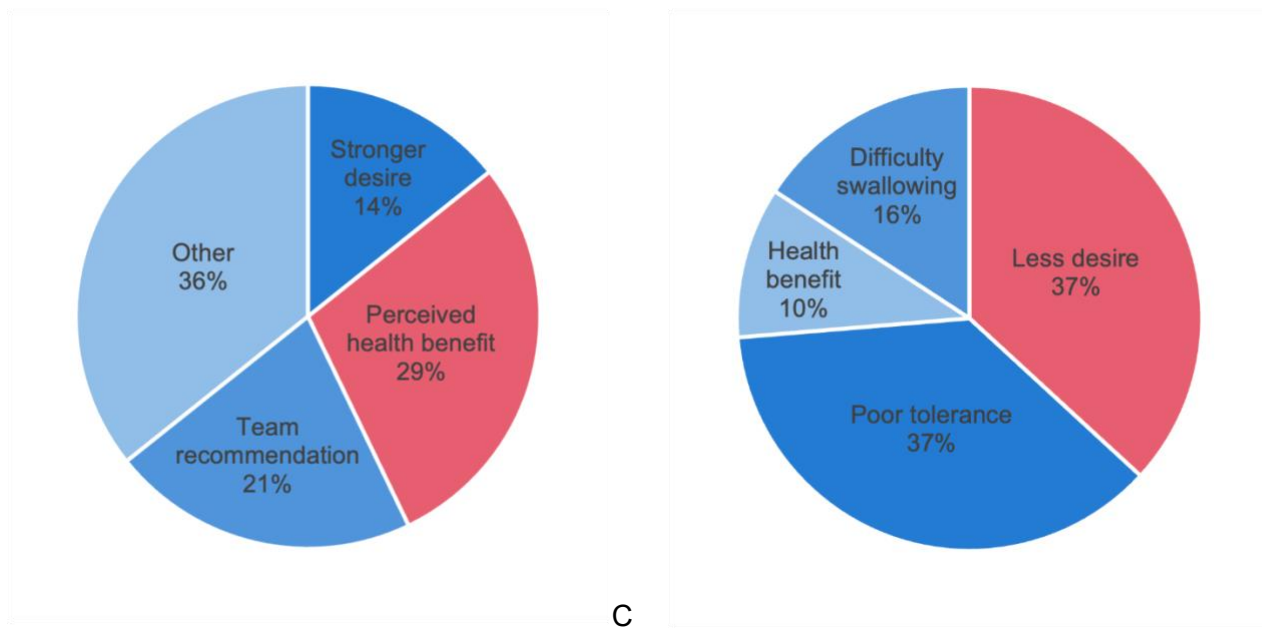


Figure 6A-D - Analysis of dietary changes and rationale. Categorised by: (A) Type of change, (B) Volition, (C) Rationale for addition of certain food items (n = 14), and (D) Rationale for removal of certain food items (n = 19).

The pie charts summarise how patients' food intake changed over time, the extent to which these changes were intentional, and the reasons for adding or removing certain food items from their diet (figure 6A-D). As shown in figure 6A, most patients either maintained or decreased their overall food intake (42% and 33%, respectively). When asked about the volition of these changes, more than half (54%) reported having deliberately modified their diet (figure 6B). Partial volition (23%) was for example related to practical constraints during radiotherapy.

Patients who reported adding certain food items, mostly did so following recommendation from their treatment team (21%), because they perceived these foods as being beneficial for their health (29%), or simply had a stronger desire for it (14%) (figure 6C). Other contributing factors (36%) included swallowing difficulties, nausea, and an increased perceived need for energy.

Conversely, patients reporting removal of certain food items, mainly attributed this to poor tolerance (37%), less desire for certain foods (37%) and swallowing difficulties (16%) (figure 6D).

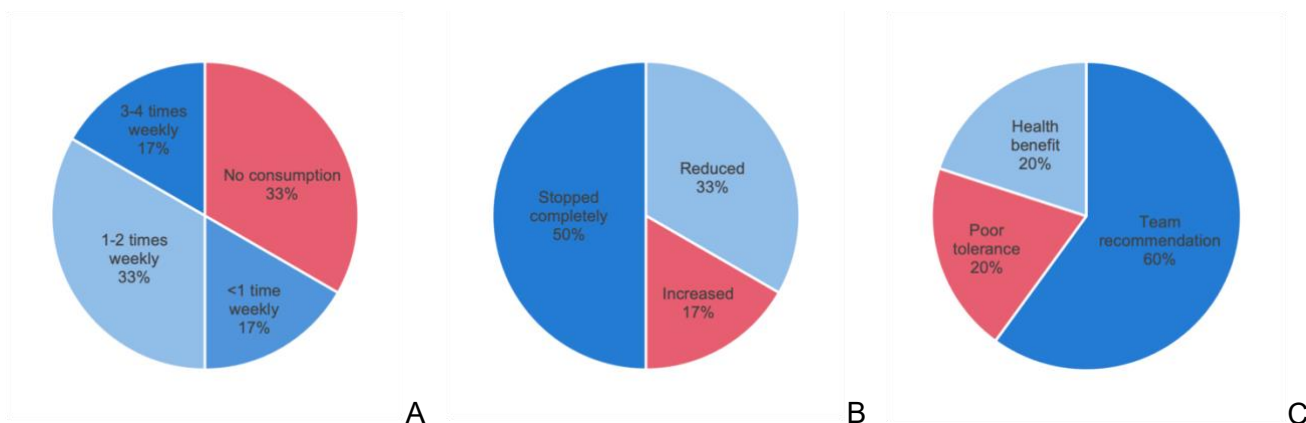


Figure 7A-D – Analysis of alcohol consumption and associated changes. Categorised by: (A) Consumption frequency prior to diagnosis, (B) Type of reported change, and (C) Rationale for decrease or cessation (n = 5).

Five out of six patients consumed alcohol prior to their diagnosis, with a heterogeneous distribution in drinking frequency (figure 7A). Most patients reported a decrease or complete cessation of alcohol use following diagnosis (figure 7B). One patient who consumed five or more units three to four times per week before diagnosis gradually reduced intake after diagnosis and stopped alcohol completely upon initiation of chemotherapy. Reported reasons for decreased consumption included recommendations by healthcare professionals (60%), poor tolerance (20%), and perceived health benefits (20%) (figure 7C). Before diagnosis, only one patient smoked approximately one package per day for ten years. After diagnosis, this patient quit smoking entirely following medical advice.

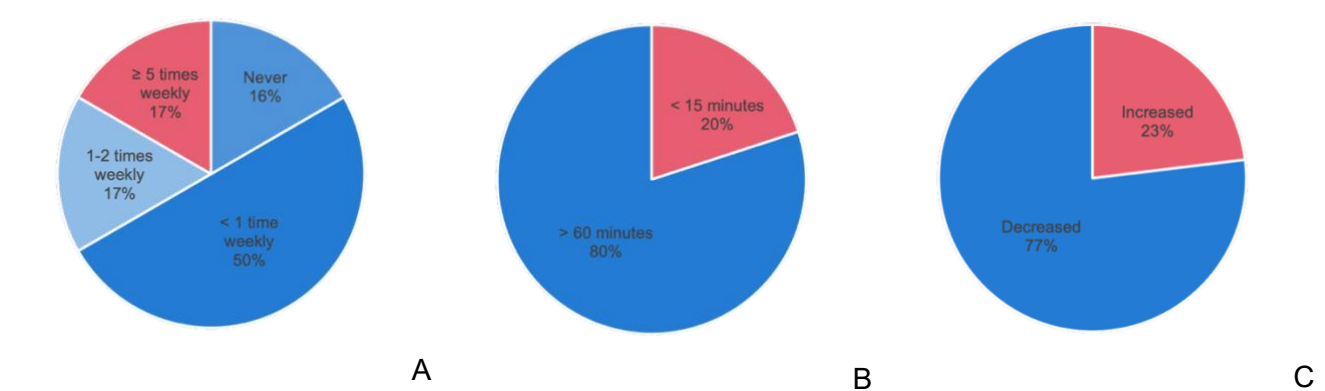


Figure 8A-C – Analysis of exercise habits prior to diagnosis and reported changes. Categorised by: (A) Exercise frequency prior to diagnosis, (B) Exercise duration prior to diagnosis, (C) Type of reported change.

Five of the six patients engaged in physical activity, although most did so less than once a week (figure 8A). When they exercised, sessions typically lasted more than one hour (figure 8B). During treatment, most patients (77%) gradually reduced their activity levels due to fatigue, time constraints, or pain (figure 8C). In contrast, increased exercise (23%) was reported when pain was less pronounced or with support from a physiotherapist.

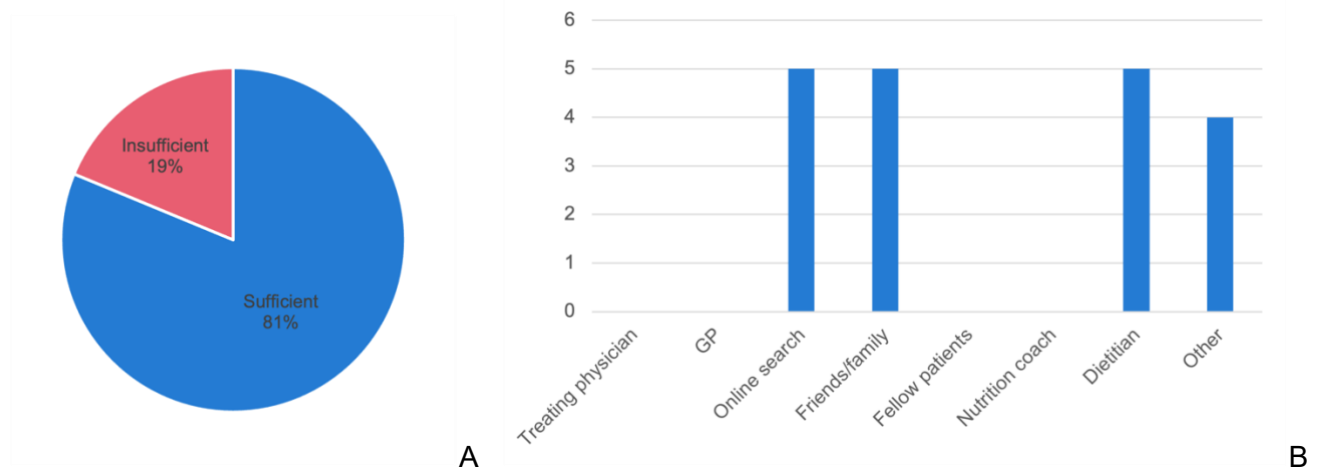


Figure 9A-B - Nutritional information. Categorised by: (A) Sufficiency of nutritional information, and (B) Reported sources of nutritional information. Abbreviations: GP, general practitioner.

Throughout the treatment period, most patients (81%) reported having sufficient nutritional information to make informed decisions about their diet (figure 9A). Among those who felt they lacked knowledge, one patient did not wish to receive additional information, while the others expressed a desire to consult a dietitian. Patients who reported having sufficient knowledge obtained information from multiple sources, including online searches, friends and family, and dietitians (figure 9B). Additional sources mentioned were the gym community, books, and AI-based recommendations, such as ChatGPT.

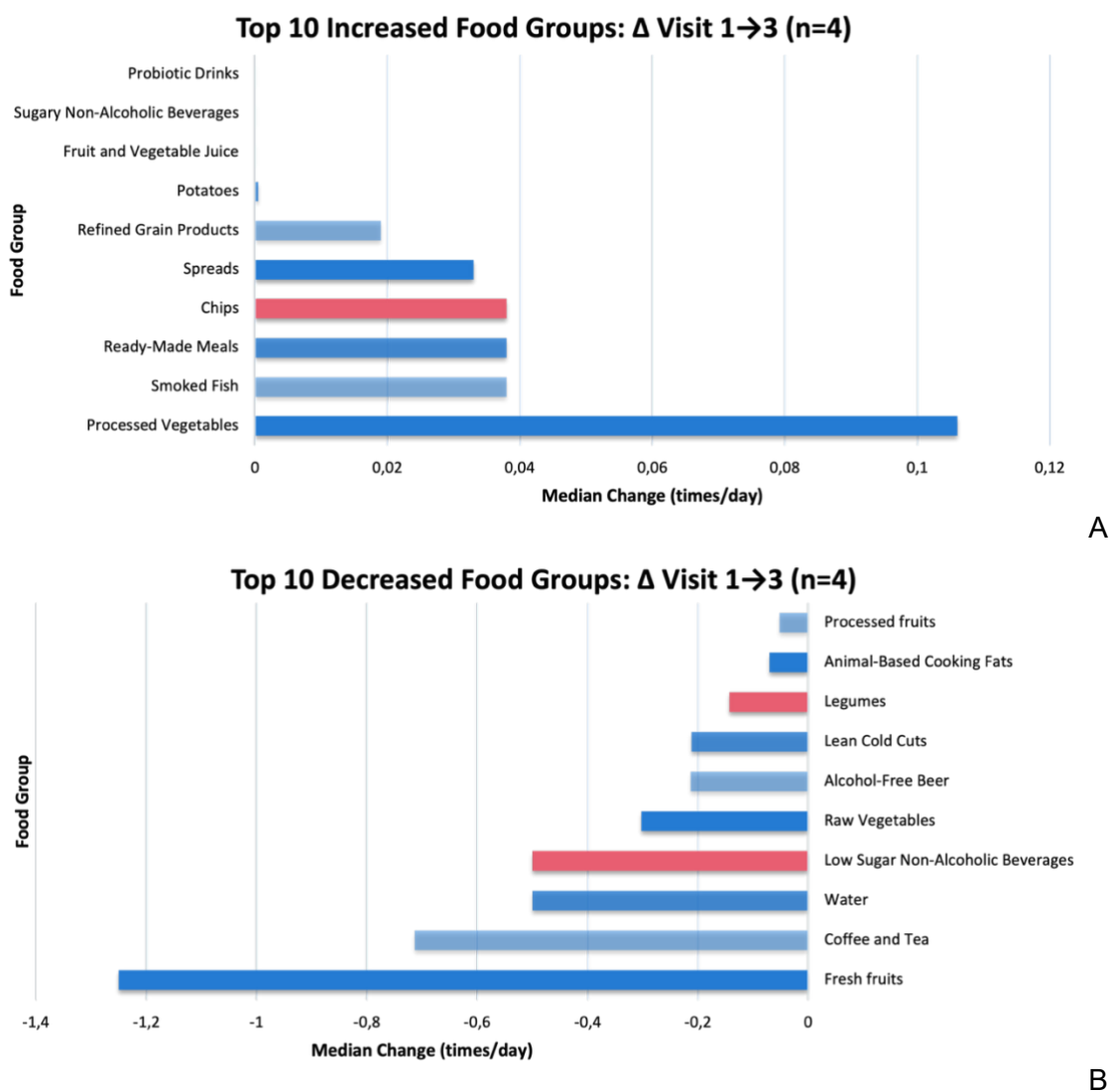


Figure 10A-B - Change in the top 10 food groups showing the greatest median increase (A) and decrease (B) in intake frequency (times/day) between Visit 1 and Visit 3 (n=4).

Across the treatment trajectory, several changes in food group intake were observed. Figures 10A and 10B present the ten largest increases and decreases in food groups between the first and last visit, expressed as the median change in daily consumption. Changes in food group intake between the first and second, and between the second and last visit are shown in appendix 12A-D.

During the first half of treatment, intake of ready-made meals, fruit and vegetable juice, eggs, bakery products, and fresh and frozen fish slightly increased. Consumption of water decreased the most,

followed by fresh fruit, coffee and tea, lean cold cuts, and low sugar non-alcoholic beverages (appendix 12A-B). During the second half of treatment, patients reported an increase in water, processed vegetables, fresh fruit, smoked fish, and lean cold cuts. Consumption of fresh and frozen fish, legumes, processed fruit, ready-made meals, and raw vegetables decreased (appendix 12C-D).

Overall, across the entire treatment period, increases were observed in processed vegetables, smoked fish, ready-made meals, chips, and spreads. Decreases were observed in fresh fruits, coffee and tea, water, low sugar non-alcoholic beverages, and raw vegetables (figure 10A-B).

Median changes in daily consumption were small across all food groups, with the largest change corresponding to a decrease in water intake of –1.2 consumptions per day.

Current practices in nutritional support

At the start of therapy, patients receive a brochure providing practical guidance, including strategies to manage taste and smell changes and to increase their energy and protein intake. Hospitalised patients are screened on admission using the NRS 2002, and a dietitian is consulted, typically at bedside, if a high risk of malnutrition is identified. While a high-risk score does not automatically trigger a predefined intervention, these patients are closely monitored and receive tailored nutritional counselling according to individual needs and ESPEN recommendations. Dietitians explore potential causes of reduced intake such as therapy-related side effects, stress, or comorbidities, and provide practical, patient-specific advice. Dietitians may also become involved whenever deemed necessary by physicians, nurses, or other healthcare professionals. Patients can also request a consultation themselves. Between January 1st and July 30th, 2025 35 sarcoma patients were treated at UZ Gent, of whom 26 were seen by a dietitian.

Discussion

This mixed methods pilot study explored the nutritional status of sarcoma patients undergoing neoadjuvant chemotherapy or radiotherapy, focusing specifically on the value of MUAC and post-diagnostic dietary changes. Despite the small sample size, this study provides valuable preliminary insights into nutritional assessment methods, nutritional status and malnutrition diagnosis in this underexplored patient group. The findings show modest declines in anthropometric parameters during treatment and heterogeneous dietary adaptations among patients. Moreover, this study highlights the value of MUAC as nutritional assessment tool as well as the feasibility of weight and MUAC home-based measurements. These results are discussed below in relation to previous literature and potential implications for future research and clinical care.

The nutritional status of patients was evaluated by longitudinally tracking multiple anthropometric parameters across three hospital visits. Roop et al. also assessed nutritional status in sarcoma patients using the PG-SGA (50). This comprehensive tool integrates patient-reported symptoms, dietary intake, and a clinical assessment of fat and muscle stores. However, muscle mass is estimated through observation and palpation rather than objective anthropometric measurements such as MUAC, and only weight and height are measured quantitatively. In this study, on average, all parameters showed a modest overall decline, although substantial interindividual variability was observed. Some patients demonstrated marked increases or decreases in specific parameters. For example, while mean MUAC decreased by only 1.5%, one patient experienced a pronounced reduction of 7% (absolute loss of 2.5 cm). Given the small sample size, these individual fluctuations explain why the average changes are modest compared to some individual trajectories.

The heterogeneity in nutritional evolution observed among patients is noteworthy. While some patients gained weight or maintained stable anthropometric values, others clearly showed signs of deterioration, suggesting progression towards malnutrition. This variability emphasizes the multifactorial nature of malnutrition, which is not only influenced by the heterogeneous disease itself but also by individual characteristics, treatment modalities, and metabolic responses. In sarcoma specifically, where unhealthy lifestyles are typically not associated with its incidence, this highlights the importance of assessing patients' baseline nutritional status and body composition to identify those at risk. Interestingly, the baseline average BMI and WHR of this study sample indicated overweight and increased metabolic risk, reflecting global rise in obesity. Nevertheless, malnutrition and overweight are not mutually exclusive; muscle wasting can occur despite excess adiposity, underlining the need to assess body composition rather than weight alone.

The GLIM criteria were developed to standardise nutritional assessment and the diagnosis of malnutrition. This study aimed to evaluate their application in sarcoma patients. The need for standardised diagnostic criteria is highlighted by Eu et al., who reported a prevalence of malnutrition

ranging from 13.3 to 45.9% in sarcoma patients depending on the used screening tool, none of which applied the GLIM criteria (51). In oncology, GLIM diagnosis of malnutrition depends on the phenotypic criteria of low BMI, unintentional weight loss, or reduced muscle mass. Relying solely on low BMI, risks missing malnutrition in patients with overweight or obesity. A limitation reflected in this study, where none of the patients fulfilled the BMI criterion. Besides, the value of BMI as a nutritional assessment tool has repeatedly been questioned, as it scales weight to height without differentiating between lean and fat tissue. Weight loss percentage over time may serve as a more sensitive criterion, yet even this measurement can hide malnutrition when muscle mass is lost while fat mass increases. In our cohort, none of the patients demonstrated this discordance. Additionally, body weight measurements may be confounded by fluid administration in patients undergoing chemotherapy, potentially affecting the accuracy of this criterion.

The so-called 'obesity paradox', also called the 'BMI paradox', is the observed association between higher BMI and improved survival in cancer patients, despite obesity being a known risk factor for cancer incidence. This further highlights the limitations of BMI. A likely explanation is that patients with higher BMI often possess greater muscle reserves, which are protective during treatment (52). Therefore, reduced muscle mass is an important third parameter to consider in assessing malnutrition. In this study, only one patient received a GLIM-based malnutrition diagnosis due to reduced muscle mass. However, due to practical constraints, this patient was only assessed the first time during the second chemotherapy cycle, missing the initial phase of weight loss. Consequently, 'only' 3.1% reduction in weight was recorded. When pre-treatment weight was considered, this patient met the GLIM criterion of > 5% weight loss within 6 months. An interesting study by Casirati et al. evaluated the application of GLIM criteria in retroperitoneal sarcoma (RPS), specifically assessing whether the phenotypic criteria are applicable and interchangeable. The findings show comparable insights about BMI and weight loss, reflecting their limited ability to account for altered body composition, which is particularly important in RPS due to the presence of voluminous tumours (53).

GLIM proposes several methods to determine low muscle mass (appendix 13). Technical assessment techniques include BIA, CT, DXA and ultrasound, while anthropometric measurements, such as MUAC and calf circumference, have also been proposed (54). Technical methods are often expensive, time-consuming and do not allow for frequent reassessments over time. In this regard, anthropometric measurements are more suitable for routine clinical practice (54). This study focused on MUAC as a promising tool for assessing reduced muscle mass due to its ease of use in various settings, both outpatient and inpatient. Moreover, recent evidence suggests that lower MUAC is associated with adverse clinical outcomes, further supporting its potential clinical value in oncology (32, 33, 51, 55-63).

Within the GLIM criteria, validated cut-off values exist for calf circumference, but are lacking for MUAC. Costa-Pereira et al. proposed MUAC thresholds of < 28 cm for men and < 25 cm for women, with severe malnutrition defined as < 27 cm and < 23 cm, respectively (31). Another study, specifically defining

MUAC reference values in an oncological setting, suggested a 23.4 cm cut-off for malnutrition (64). However, the latter computed cut-off values based on a BMI < 18.5 kg/m². The first study additionally applied BMI-adjusted corrections to account for overweight and obesity, which better reflects the prevalence of these conditions in developed countries (31). To facilitate the systematic use of MUAC in clinical practice, validated cut-off points or slope percentage values are needed. Strikingly, one of the patients in this study showed a considerable decrease in MUAC of 2.5 cm (7%). However, this patient did not meet the cut-off value proposed by Costa-Pereira et al. (31). This further underscores the need to validate existing cut-off values or to explore alternative slope-based MUAC criteria for malnutrition.

MUAC is a promising tool for nutritional assessment. However, it is rarely used in clinical practice, and its value is often overlooked. Originally developed as a simple field method to assess nutritional status, particularly in children from developing countries, MUAC has since been widely adopted to screen for malnutrition in adults and various clinical settings (48). One aim of this study was to examine the association of MUAC with other anthropometric measurements to further validate its utility as a nutritional assessment tool in oncology. MUAC was significantly associated with weight, BMI and hip circumference, but not with waist circumference. Due to the small sample size, these results should be interpreted with caution, and no definitive conclusions can be drawn. Significant association between MUAC and BMI was also established by Benítez Brito et al. (65). Studies examining the association between MUAC and weight, hip or waist circumference in adults were not found. Nevertheless, the findings of this study demonstrate that MUAC corresponds to other important anthropometric parameters in an oncological setting, supporting its credibility as a screening tool for malnutrition. From a practical perspective, MUAC offers the advantage of being simple, convenient, and reproducible, does not require patients to undress or remove shoes, and can even be assessed in bedridden patients.

As MUAC has proven to be a valuable and practical parameter to assess reduced muscle mass within the GLIM criteria, it is also a feasible measurement for home-based monitoring. Importantly, MUAC offers a tool for patient empowerment, allowing individuals to easily track their own nutritional and muscle status, which may enhance engagement and self-management during treatment. Although individual MUAC graphs revealed some variability between home and hospital measurements, this variation likely represents random measurement noise rather than systematic bias. Bland-Altman analyses demonstrated good overall agreement between both settings, with a mean bias close to zero and narrow limits of agreement. On a group level, these findings suggest that home-based MUAC measurements can reliably reflect in-hospital values, even though minor individual fluctuations may occur. Weight showed an even stronger agreement, further supporting the feasibility of self-monitoring, whereas hip and waist circumferences showed greater variability, as reflected by broader limits of agreement, making them less suitable for home measurements.

Comparable findings have been reported in other populations. In a paediatric study on at-home surveillance of children with severe acute malnutrition, caregiver-nurse agreement for MUAC reached

77-80% after brief training, indicating that even limited instructions can provide reliable MUAC assessment outside the hospital setting (66). Similarly, in adults, self-measured waist and hip circumferences following standardised video instructions demonstrated high reliability with intraclass correlation coefficients of 0.97 and 0.96, and nearly all differences within Bland-Altman limits of agreement (67). The greater variability observed in our study may therefore reflect differences in training, highlighting the importance of clear and standardised instructions when implementing self-measurements in clinical populations. From a practical perspective, MUAC was the easiest parameter for patients to measure accurately by themselves. The anatomical landmark – located halfway between the acromion and the olecranon – is straightforward to identify, and the risk of measurement error therefore appears limited. In contrast, hip and waist circumferences were often measured at different heights or at oblique angles despite clear instructions, since maintaining a level tape around longer body distances is more challenging. Overall, based on our findings, MUAC appears both more reliable and user-friendly for self-measurements, while also adequately capturing longitudinal changes during treatment compared to waist or hip circumference.

Although MUAC is an accessible and reliable parameter for both in-hospital and home-based monitoring, it is not yet implemented in routine clinical practice at UZ Gent. Nutritional screening currently relies primarily on the NRS-2002 and clinical judgement, with limited systematic assessment of muscle mass. However, findings from the Belgian ONCOCARE study indicate that physician-based clinical judgement markedly underestimates malnutrition prevalence compared to structured tools as the GLIM criteria (5). While the GLIM criteria are known, they are not routinely applied, partly because no standardised intervention is linked to the identification of malnutrition. This gap highlights the need for objective and easily applicable tools to detect and monitor malnutrition risk at an early stage in sarcoma patients. Moreover, as the timing and manner of dietitian involvement vary considerably, nutritional care lacks a standardised pathway, which may lead to delayed or missed diagnoses.

In our cohort, 26 of 35 sarcoma patients (74.3%) were seen by a dietitian during their treatment. This proportion is notably higher than previously reported in broader oncological populations, where 39-46% of patients received dietetic counselling at any point throughout their treatment (68, 69). The higher rate of dietitian involvement in sarcoma patients at UZ Gent may partly reflect the typically later presentation of sarcoma patients, and the typically longer, more intensive trajectories compared to the more common tumour types. In addition, sarcomas often affect the limbs, especially the lower extremities, thereby limiting physical activity, which may further predispose these patients to malnutrition. However, as no data could be found on dietitian involvement specifically in sarcoma care, direct comparisons with similar cohorts were not possible.

Dietary changes observed in this study were highly heterogeneous, reflecting the diversity in treatment modalities, individual experiences, and coping strategies among sarcoma patients. Most patients reported some degree of modification in their dietary habits since diagnosis, although the direction and

magnitude of change varied substantially. A notable finding was that lifestyle factors such as alcohol consumption and smoking were frequently reduced, suggesting that patients were able to follow professional advice effectively. In line with this, intake data indicated a decrease in alcohol and processed meat consumption, while protein- and energy-rich foods such as eggs and fish were more frequently reported, consistent with nutritional counselling goals. At the same time, the observed increase in ready-made and processed foods may reflect a need for convenience or adaptations to side effects such as fatigue or dysphagia. Nutritional adaptations appeared to be more frequent among patients undergoing chemotherapy, likely driven by treatment-related side effects such as nausea, taste alterations, or mucositis. Given that only one radiotherapy patient was included, no conclusions can be drawn regarding their specific patterns of dietary change. These findings suggest that treatment context, particularly chemotherapy, plays an important role in shaping short-term dietary behaviour in this population.

Most participants indicated that they had received sufficient nutritional information, often through consultations with a dietitian. This is encouraging, as evidence from nutrition counselling studies suggests that early, individualised dietary guidance can help mitigate treatment-related malnutrition (35). While the role of treating physicians in providing dietary guidance was less prominent, this does not necessarily reflect a gap in care, as patients actively sought information from multiple sources. Clarifying the potential contributions of physicians within the multidisciplinary team could further support consistent messaging and reinforce patient confidence in dietary decisions. From a broader perspective, the observation that patients actively modify their dietary patterns to alleviate side effects, regain a sense of control, or to promote recovery illustrates the central role of nutrition in patient empowerment during cancer treatment. Food is one of the few aspects of therapy that patients can directly influence themselves, and this autonomy may contribute positively to their perceived well-being.

Interestingly, the only patient identified as malnourished according to the GLIM criteria also experienced chemotherapy-related neutropenia, febrile neutropenia, and oesophagitis. This observation aligns with existing evidence linking poor nutritional status and low muscle reserves to greater treatment-related toxicity. Notably, this patient also adapted their diet by shifting towards softer foods, primarily dairy products, to manage swallowing difficulties caused by oesophagitis. While this single case does not allow for generalisation, it exemplifies the complex interaction between nutritional status, treatment tolerance, and adaptive dietary behaviour during neoadjuvant therapy.

As a pilot study in a rare and heterogeneous patient population, this work has several inherent limitations. The small sample size limits statistical power and prevents robust subgroup analyses, meaning that the findings should be interpreted as exploratory rather than definitive. Assessing the association between MUAC and the GLIM diagnosis of malnutrition was therefore not feasible. Treatment heterogeneity introduced variability, as patients underwent different neoadjuvant regimens (chemotherapy or radiotherapy). Moreover, radiotherapy patients were partly treated in peripheral

hospitals, resulting in their underrepresentation, which limits conclusions about this subgroup. Two participants had incomplete follow-up, and the observation window was restricted to the neoadjuvant phase, without postoperative or long-term evaluation. Measurement-related factors may have also influenced the results. Body weight was affected by fluid shifts, particularly in patients measured shortly after receiving chemotherapy, as well as by tumour mass and measurement timing. Furthermore, body composition could not be assessed using technical methods such as bioelectrical impedance analysis.

Regarding dietary changes, limitations include the highly heterogeneous modifications reported by patients, influenced by treatment side effects, personal preferences, and coping strategies. The use of a qualitative FFQ precluded a quantitative assessment of macro- and micronutrient intake. Because the FFQ was strictly qualitative, it did not allow for a quantitative assessment of macro- and micronutrient intake. Furthermore, recall bias may have affected patient reporting. Additionally, the small number of radiotherapy patients prevents meaningful conclusions about treatment-specific dietary patterns. Despite these limitations, the study demonstrates the feasibility of longitudinal anthropometric follow-up during neoadjuvant treatment.

Future research should aim to include larger, possibly multicentric cohorts with extended follow-up to capture postoperative recovery and nutritional trajectories during adjuvant therapy, if needed. Further validation of MUAC as a nutritional marker in oncology is warranted, as clinically relevant cut-off values remain to be established. Since hip and waist circumference showed limited reproducibility and are not part of the GLIM criteria, future studies might focus primarily on MUAC as the most practical and meaningful anthropometric measurement. Improving the accuracy of self-measurements through more detailed written or video instructions, or the use of self-retracting measurement tapes, could enhance data quality.

To address dietary changes more comprehensively, future studies could use 24-hour dietary recalls or other detailed assessments such as three-day dietary records, ideally supported by dietitians, to accurately quantify macro- and micronutrient intake. Such assessments, however, require professional interpretation and introduce additional workload for both patients and study personnel. Investigating the relationship between dietary changes and nutritional status over time, including postoperative and long-term follow-up, would provide further insights. Clarifying the roles of oncologists, dietitians, and other healthcare providers in nutritional counselling may help streamline guidance, while continuing to empower patients to actively manage their own diet throughout treatment. Finally, it would be valuable for future studies to explore the integration of MUAC into routine nutritional screening and to investigate the role of cancer nurses in supporting both in-hospital and home monitoring, in order to determine whether this approach could serve as a simple, patient-friendly tool in sarcoma care (70).

In conclusion, this mixed methods pilot study provides preliminary evidence supporting the clinical value of MUAC as a simple, reliable, and feasible anthropometric measurements for monitoring nutritional status in sarcoma patients undergoing neoadjuvant therapy. MUAC demonstrated strong associations with conventional anthropometric measurements, such as BMI and weight, and good agreement between hospital- and home-based assessments. This suggests its potential as a practical alternative for evaluating muscle mass within the GLIM framework and for detecting nutritional decline over time. The observed heterogeneity in nutritional trajectories highlights the importance of individualised, longitudinal assessment within a standardised nutritional care pathway. Collectively, these findings lay the groundwork for future studies to further validate MUAC and to optimise early detection and management of malnutrition in sarcoma care.

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Appendix

Appendix 1: Thresholds for severity grading of malnutrition according to the GLIM criteria

Phenotypic criteria	Stage 1 – Moderate malnutrition	Stage 2 – Severe malnutrition
Low BMI (kg/m²)	< 20 (if < 70y) or < 22 (if ≥ 70y)	< 18.5 (if < 70y) or < 20 (if ≥ 70y)
Weight loss (%)	5-10% within the past 6 months or 10-20% beyond 6 months	> 10% within the past 6 months or > 20% beyond 6 months
Reduced muscle mass	Mild to moderate deficit (per validated assessment method)	Severe deficit (per validated assessment method)

The grade of malnutrition is determined by the highest severity level of any phenotypic criterion fulfilled.

Abbreviations: GLIM, Global Leadership Initiative for Malnutrition; BMI, body mass index.

Mid-upper arm circumference and clinical outcomes in cancer patients: a systematic review

Abstract

Background: Malnutrition affects up to 70% of cancer patients and is associated with poorer survival, increased treatment-related toxicity, postoperative complications, and reduced quality of life. Early assessment of muscle mass is essential, yet technical methods are resource-intensive. Mid-upper arm circumference (MUAC) is a simple, practical measure of primarily muscle reserves that is commonly used in low-resource settings. However, its prognostic value in oncology remains unclear. This systematic review aims to evaluate whether MUAC can serve not only as a screening tool but also as a predictor of clinically relevant outcomes in cancer patients.

Methods: A systematic review was conducted of observational and interventional studies assessing associations between MUAC and clinical outcomes in cancer patients. Studies including any cancer type, stage, age, or treatment modality were eligible; studies on long-term survivors were excluded. Embase, PubMed, and Scopus were searched up to August 2025. The methodological quality of the included studies was assessed using CASP.

Results: Nineteen studies were included, examining diverse malignancies and patient populations. Associations between MUAC and survival and mortality outcomes were mixed, with poorer overall and event-free survival in some studies, while others found no significant associations. Chemotherapy-related toxicity and postoperative complications showed inconsistent associations with MUAC. Lower MUAC was more consistently linked to poorer functional status, higher frailty, and reduced quality of life. Limited evidence indicated higher pretreatment neutrophil-to-lymphocyte ratio in patients with lower MUAC.

Discussion: This review highlights the growing interest in MUAC's clinical relevance in oncology, with most studies published since 2020. Lower MUAC was frequently associated with poorer clinical outcomes. However, evidence was heterogeneous due to variations in cancer type, treatment, age, measurement timing, and MUAC cut-offs. Despite limitations, MUAC appears to be a simple and practical tool for assessing nutritional status and potentially predicting clinical outcomes. Further high-quality prospective studies with standardised MUAC cut-offs and harmonised measurement timing are warranted to clarify its predictive value and support integration into routine cancer care.

Introduction

Mid-upper arm circumference (MUAC) is a simple anthropometric measurement that has long been used as a cornerstone for detecting and managing malnutrition in low-resource settings, particularly among children. Within community-based management of acute malnutrition (CMAM) programs, MUAC enables large-scale screening and early treatment of severe acute malnutrition (SAM) through its accuracy, affordability, and ease of use by trained community health workers (1). The World Health Organization (WHO) and UNICEF have endorsed MUAC as a standard measurement for identifying SAM in children aged 6-59 months, with a cut-off of <115 mm allowing early detection before severe complications arise (2). Reflecting primarily the muscle reserves of the upper arm, MUAC remains one of the most widely applied anthropometric tools in nutritional surveillance systems across low- and middle-income countries (3).

Malnutrition is a frequent yet often underrecognised complication in cancer, affecting approximately 20-70% of patients depending on tumour type, stage, and patient age (4-6). It is particularly prevalent among older adults and those with advanced disease, with the highest rates reported in gastroesophageal, lung, and head and neck cancers (6). Gastroesophageal cancers may impair swallowing and digestion, while lung and pancreatic cancer may involve cachexia-inducing mechanisms, increasing vulnerability to nutritional decline (6). A recent Belgian multicentre study using the Global Initiative on Malnutrition (GLIM) criteria reported malnutrition in 26.3% of patients at diagnosis, rising to 61.1% four months after treatment initiation, illustrating the progressive nature of nutritional decline during therapy (7).

The consequences of malnutrition in cancer extend far beyond weight loss alone. Malnourished patients experience poorer overall and disease-free survival, higher rates of postoperative complications and infections, and prolonged hospitalisation (8-12). It also compromises treatment tolerance, contributing to dose reductions, treatment delays, and reduced efficacy of chemo- and radiotherapy (6). Beyond these clinical outcomes, malnutrition also impairs functional status, increases psychosocial distress, and diminishes quality of life (6, 12, 13).

Given the substantial impact of malnutrition in oncology, early and reliable assessment of muscle mass is crucial. The GLIM criteria identify reduced muscle mass as a key phenotypic feature of malnutrition (14). While technical methods such as CT or DXA provide precise body composition estimates, they are resource-intensive and impractical for repeated monitoring (15). Consequently, MUAC is emerging as a simple, practical, and reproducible tool to estimate muscle reserves in cancer patients (16).

Despite its utility in diagnosing malnutrition, the prognostic value of MUAC in oncology remains unclear. Evidence linking MUAC to clinically meaningful outcomes such as overall survival, treatment-related toxicity, length of hospital stay, and postoperative complications is limited and scattered across heterogeneous oncological populations. Therefore, this systematic review aims to clarify whether MUAC can serve not only as a screening tool, but also as a predictor of clinical outcomes in oncology.

Methods

According to the aim of this systematic review, observational and interventional studies reporting associations between mid-upper arm circumference (MUAC) and clinical outcomes in cancer patients were considered eligible. Studies were included if they reported MUAC measurements in patients with any cancer type, stage, age, gender, race, or ethnicity. Studies focusing exclusively on patients in remission or long-term cancer survivors were excluded. Reviews, meta-analyses, abstracts, conference papers, study protocols, and non-English articles were excluded. Studies reporting additional outcomes relevant to patient health status or prognosis were also considered, even if they did not strictly represent direct clinical outcomes.

A systematic search was performed in Embase, PubMed, and Scopus from database inception up to August 27, 2025. The following search strategies were used:

- **Embase:** (MUAC OR 'mid-upper arm circumference' OR 'mid upper arm circumference') AND 'neoplasm'/exp
- **PubMed:** ("mid upper arm circumference" OR "mid-upper arm circumference" OR "MUAC") AND (cancer OR neoplasm* OR tumor* OR tumour* OR malignan* OR carcinoma* OR oncolog* OR neoplasia OR "Neoplasms"[Mesh])
- **Scopus:** TITLE-ABS-KEY (MUAC OR "mid upper arm circumference" OR "mid-upper arm circumference") AND TITLE-ABS-KEY (cancer OR tumor* OR tumour* OR malignan* OR carcinoma* OR oncolog* OR neoplas*)

All search results were imported into EndNote and Rayyan. Duplicate records were removed using both Endnote's and Rayyan's automated deduplication tool and followed by manual removal of undetected duplicates. Two reviewers independently screened titles and abstracts according to the predefined eligibility criteria. Records for which eligibility remained unclear were retained for full-text assessment. Full texts were reviewed independently by both reviewers. Disagreements were resolved through discussion or, if necessary, by a third reviewer who made the final decision. The study selection process is illustrated in a PRISMA 2020 flow chart.

Data extraction was performed independently and in duplicate using predesigned extraction forms. Extracted data included study characteristics (author, year, country, study design, sample size), participant characteristics (age, cancer type, treatment modality), and reported clinical outcomes of interest (e.g. mortality, survival, post-operative complications, length of hospital stay, and quality of life). The reported significance levels (p-values, confidence intervals, or effect estimates) were extracted as presented in the original studies. When information was missing or unclear, it was reported as unavailable.

The methodological quality of included studies was assessed by one reviewer with AI assistance using the design appropriate Critical Appraisal Skills Programme (CASP), 2024 checklists.

Given the expected heterogeneity in study designs, MUAC measurement timing, and reported clinical outcomes, a meta-analysis was not feasible. Findings were therefore synthesised narratively and presented under thematic subheadings. The planned assessment of certainty

of evidence for each clinical outcome was to be conducted using the GRADE approach, where feasible.

The review protocol was registered in PROSPERO (CRD420251107393). The review was conducted in accordance with PRISMA 2020 guidelines.

Results

Study selection

A total of 571 records were identified through database searching in PubMed, Embase and Scopus. After removing duplicates ($n = 263$), 308 unique records were screened by title and abstract. After this screening, 52 articles were retained for full-text review. Of these, 19 could not be retrieved because the full-text was unavailable online ($n = 7$) or only an abstract was accessible ($n = 12$). Ultimately, 33 full-texts were assessed for eligibility, of which 19 met the inclusion criteria and were included in the final analysis. A detailed overview of the study selection process is presented in figure 1.

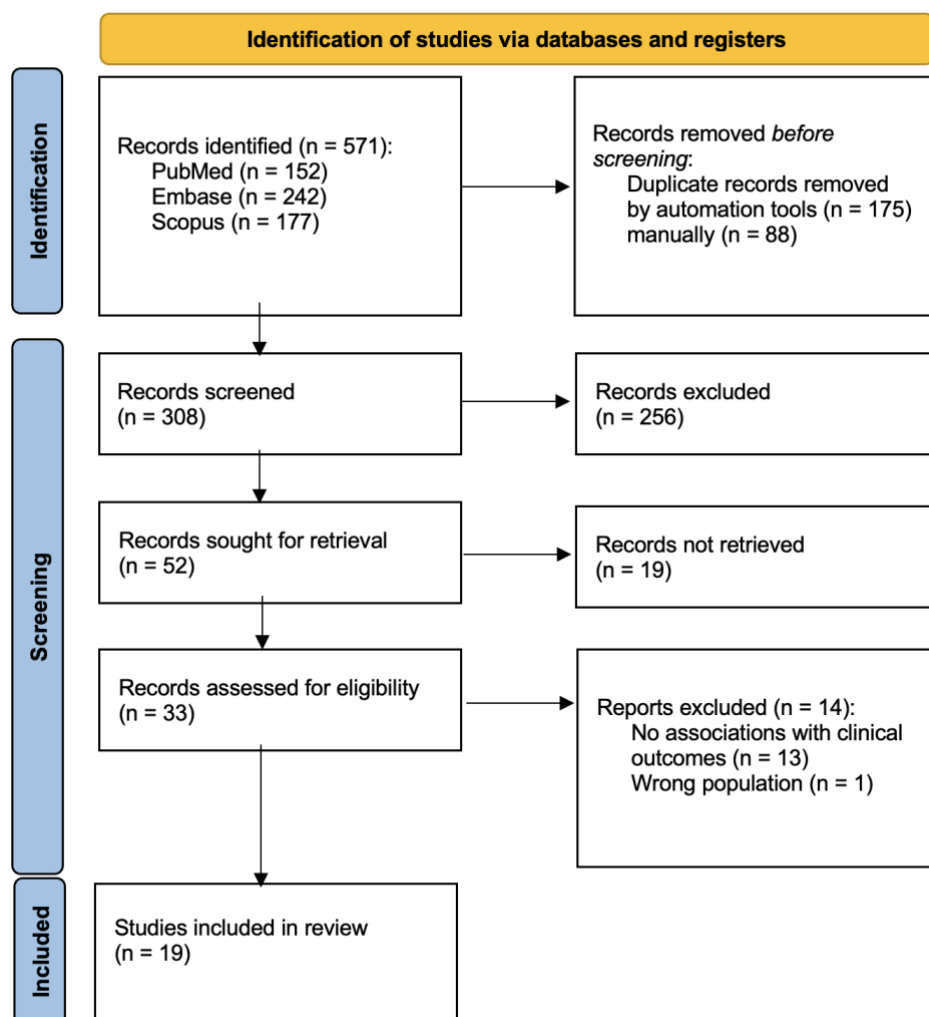


Figure 11 - PRISMA flowchart.

Study characteristics

A total of 19 studies met the inclusion criteria for the systematic review. Detailed characteristics of the included studies are presented in table 1.

Table 6 - Study characteristics.

Author (year)	Country	Study design	Sample size	Cancer type	Treatment modality	Age	Timing MUAC	MUAC cut-off
Arora et al. (2023)	India	Prospective observational	159	HNSCC	Unspecified	56.3 ± 13.27	Pre- and posttreatment	< 21 cm
Draper et al. (2018)	South Africa	Prospective observational	77	Nephroblastoma	Cht, RT	4.7 ± 2.9	Pretreatment	Frisancho standards
Eu et al. (2019)	Malaysia	Prospective observational	85	Sarcoma or bone metastasis	Surgery, neoadjuvant Cht (n=14)	Age groups: ≤ 20 (12.9%) 21-40 (18.8%) 41-60 (29.4%) 61-80 (35.3%) ≥ 81 (3.5%)	Preoperative	≤ 21 cm
Guzmán-León et al. (2025)	Mexico	Retrospective observational	252	ALL	MAS-ALL18 protocol	5.6 [7.7]	Pretreatment	< -1 Z (Z-scores for age and sex)
Hou et al. (2023)	United States	Prospective observational	4535	Unspecified	Unspecified	Unspecified	Possible at any time	Q1 (≤ 29.3)
Jung et al. (2022)	South Korea	Cross-sectional	200	Various	Palliative	64.5 ± 11.5	In palliative setting	< 26.5 cm
Leandro-Merhi et al. (2017)	Brazil	Cross-sectional	300	Various	Surgery	Age groups: < 60 (48.7%) ≥ 60 (51.3%)	Preoperative	≤ P15 by Frisancho for adults, by Burr & Philips for older adults
Lu Shin et al. (2020)	Malaysia	Cross-sectional	163	Breast cancer	Various	50.34 ± 10.22	During treatment	/
Movahed et al. (2020)	Iran	Prospective observational	71	Oesophageal cancer	CRT	66.3 ± 12	Pre- and posttreatment	/
Pedro et al. (2023)	Brazil	Cross-sectional	111	Various	Various	8.5 [3.7–13.7]	Possible at any time	< P5 by WHO
Salifu et al. (2024)	Ghana	Prospective observational	133	Various	Cht	Age groups: < 12 months (7.5%) 12-59 months (45.1%) 60-119 months (25.6%) 120-155 months (21.8%)	Pretreatment	< -2 Z by WHO charts (6-59 months); by Mramba (≥ 5 years)

Author (year)	Country	Study design	Sample size	Cancer type	Treatment modality	Age	Timing MUAC	MUAC cut-off
Schoeman et al. (2025)	South Africa	Prospective observational	320	Various	Unspecified	5.3 [2.6–9.1]	Pre-, during, and posttreatment	< -2.15 Z by WHO charts (6-59 months); by Mramba (≥ 5 years)
Simarmata et al. (2023)	Indonesia	Prospective observational	42	ALL	Cht	7.2 $\pm$ 4.2	Pretreatment	$\leq$ P5 by Frisancho
Swain et al. (2018)	United Kingdom	Retrospective observational	314	Peritoneal malignancy	CRS and HIPEC	Unspecified	Preoperative	< 23.5 cm
Viani et al. (2021)	Brazil	Retrospective observational	366	Various	Unspecified	7.9 (95% CI: 7.4-8.4)	Pretreatment	< P5 by WHO (3-60 months); by Frisancho (> 60 months)
Yilmaz et al. (2020)	Turkey	Prospective observational	120	Hematologic malignancy	Unspecified	53.6 $\pm$ 14.1	Possible at any time	< 25 cm
Zhuang et al. (2022)	China	Retrospective observational	16 104	Various	Various	58 [50–65]	Pretreatment	< 24.5 (women); < 23.2 (men)
Bakir et al. (2025)	Turkey	Prospective observational	72	Upper GI tumour	Surgery	Frail (n = 38): 74.0 [65.0-79.0] Pre-frail (n = 34): 68.0 [65.0-80.0]	Pre- and posttreatment	/
Kim et al. (2022)	South Korea	Retrospective observational	200	Various	Palliative	64.4 $\pm$ 11.6	In palliative setting	< 23.0 cm (12-week survival) and < 24.5 cm (24-week survival) according to Youden's index

Data in the 'age' column are presented as mean $\pm$ SD, median [IQR], or age groups, with ranges or 95% CI, as reported in the original study. Abbreviations: CI, confidence interval; IQR, interquartile range; n, number of participants; P, percentile; Q, quartile; SD, standard deviation; ALL, acute lymphoblastic leukaemia; Cht, chemotherapy; CRS, cytoreductive surgery; CRT, chemoradiotherapy; GI, gastrointestinal; HIPEC, hyperthermic intraperitoneal chemotherapy; HNSCC, head and neck squamous cell carcinoma; MAS-ALL18, protocol for acute leukaemia; MUAC, mid-upper arm circumference; RT, radiotherapy; WHO, World Health Organization.

The included studies were published between 2017 and 2025. Specifically, 15 of the 19 (78.9%) studies included were published in 2020 or later.

The geographical distribution of the studies is notably diverse. Brazil contributed the highest number of publications ($n = 3$), followed by South Africa, Malaysia, South Korea, and Turkey, each contributing two studies. Studies from non-Western countries accounted for most of the published literature on this topic.

The majority of studies utilised a prospective observational design ($n = 10$), followed by retrospective observational studies ($n = 5$). Four studies employed a cross-sectional design.

The total patient population was 23,424 individuals. Sample sizes ranged widely, from 42 patients (Simarmata et al. (17)) to 16,104 patients (Zhuang et al. (18)). Note that one study likely reported secondary analyses of previously published cohorts (Kim et al. (19) secondary analysis of Jung et al. (20)).

The included studies examined a diverse range of malignancies, encompassing both solid tumours and haematologic malignancies. Specific tumour types included head and neck squamous cell carcinoma (HNSCC), neuroblastoma, sarcoma or bone metastasis, acute lymphoblastic leukaemia (ALL), breast cancer, oesophageal cancer, peritoneal malignancy, and upper gastrointestinal tumours. A total of eight studies included patients with various cancer types, and two studies did not report the cancer types.

Surgery (either standalone or accompanied by neoadjuvant treatment) was the most frequently reported treatment modality ($n = 4$). Chemotherapy (Cht) was also commonly reported. Two studies focused on palliative care. Conversely, five studies did not report the treatment modality.

MUAC measurement was taken at various time points across the studies. Pretreatment ($n = 8$) was the most common timing. The criteria to define malnutrition showed a wide variability. Some studies included absolute cut-offs such as < 21 cm or < 26.5 cm, others were based on Z-scores or percentiles using the Frisancho or WHO standards.

Methodological quality assessment

Table 7 - Quality assessment of included studies using the CASP checklist.

Author (year)	Methodological quality (CASP)
Arora et al. (2023)	Moderate quality
Draper et al. (2018)	Moderate quality
Eu et al. (2019)	Moderate-to-high quality
Guzmán-León et al. (2025)	Moderate quality
Hou et al. (2023)	Moderate-to-high quality
Jung et al. (2022)	Moderate-to-high quality
Leandro-Merhi et al. (2017)	High quality
Lu Shin et al. (2020)	Moderate quality
Movahed et al. (2020)	Moderate-to-high quality
Pedro et al. (2023)	Moderate-to-high quality
Salifu et al. (2024)	Moderate-to-high quality
Schoeman et al. (2025)	Moderate quality
Simarmata et al. (2023)	Moderate quality
Swain et al. (2018)	Moderate quality
Viani et al. (2021)	Moderate-to-high quality
Yilmaz et al. (2020)	Moderate-to-high quality
Zhuang et al. (2022)	Moderate-to-high quality
Bakir et al. (2025)	Moderate-to-high quality
Kim et al. (2022)	Moderate-to-high quality

CASP = Critical Appraisal Skills Programme. Each study was evaluated for methodological quality and rated as moderate, moderate-to-high, or high quality.

Study quality was evaluated using the CASP 2024 checklists appropriate for cohort and cross-sectional study designs, with the results shown in table 2. The overall methodological quality of the included studies ranged from moderate to high, with no study rated as low quality. In contrast, no study met all CASP criteria perfectly.

Most studies demonstrated moderate quality (n = 7), primarily due to small sample sizes, single-centre designs, or limited adjustment for potential confounders. These studies generally had clearly defined objectives, appropriate outcome measures, and adequate follow-up periods but were constrained by incomplete control of bias and confounding.

Several studies were rated as moderate-to-high (n = 11) or high quality (n = 1), particularly those using prospective or multicentre designs, standardized anthropometric and nutritional assessments, and multivariate analyses to account for confounders. These studies provided stronger evidence supporting the association between MUAC and clinical outcomes. Despite their methodological rigor, limitations such as retrospective data collection in some analyses, partial adjustment for covariates, and limited generalizability to diverse oncology populations were common. Additionally, all studies were observational, precluding causal inference.

Clinical outcomes

An overview of study findings on clinical outcomes is provided in table 3.

Table 8 - Clinical outcomes and findings.

Author (year)	Clinical outcome	Findings: associations with low MUAC
Arora et al. (2023)	NLR	Pretreatment median NLR significantly higher in N+ patients ($p = 0.001$); NS post treatment or in N- patients.
Draper et al. (2018)	Neutropenia	Higher frequency ($p = 0.032$) and longer duration (0.013) of neutropenia.
Eu et al. (2019)	Post-operative complications (infectious/non-infectious)	4.75 times higher risk for infectious complications ($p = 0.016$) and 5.00 times higher risk for non-infectious complications ($p = 0.018$).
Guzmán-León et al. (2025)	3-year relapse, 3-year survival	Impact of low MUAC on 3-year survival and 3-year disease relapse NS. Higher MUAC showed a decrease in the risk of relapse (HR: 0.85; 95%CI: 0.73 to 1.00; $p = 0.049$).
Hou et al. (2023)	Mortality	No consistent association with cancer mortality, although every centimetre increase was associated with an 8% decrease in mortality risk (HR: 0.92, 95% CI: 0.87 - 0.96).
Jung et al. (2022)	KPS, K-ESAS	Significantly worse KPS ($p < 0.001$) and significantly worse in 6 out of 10 K-ESAS parameters: pain ($p = 0.001$), fatigue ($p = 0.001$), nausea ($p = 0.001$), drowsiness ($p = 0.002$), loss of appetite ($p < 0.001$) and feelings of wellbeing ($p = 0.032$).
Leandro-Merhi et al. (2017)	Complications, LOHS, death	No significant associations with complications, LOHS, or death.
Lu Shin et al. (2020)	HRQoL	Significantly associated with lower GHS ($p = 0.014$) and a higher cognitive functioning ($p = 0.048$).
Movahed et al. (2020)	1-year mortality	Significant association between 1-year mortality and lower baseline MUAC ($p = 0.013$).

Author (year)	Clinical outcome	Findings: associations with low MUAC
Pedro et al. (2023)	LOS	No significant association with LOS.
Salifu et al. (2024)	Chemotherapy-related complications	Significant association with lower risk of neutropenia (HR: 0.29; p=0.045). Associations with anaemia, thrombocytopenia, febrile neutropenia, mucositis, and death NS.
Schoeman et al. (2025)	1-, 2-, and 3-year OS and EFS	Significantly associated with worse 2-, and 3-year EFS (p = 0.049 and p = 0.030, respectively). Associations with OS and 1-year EFS were NS.
Simarmata et al. (2023)	Frequency of febrile neutropenia, LOHS, duration of induction phase, remission status	Significant association with median frequency of febrile neutropenia (p = 0.04), median LOHS (p = 0.001), mean duration of induction phase (p = 0.046). Associations with remission status were NS.
Swain et al. (2018)	Duration of postoperative PN	No significant association with duration of postoperative PN.
Viani et al. (2021)	10-year OS	No significant association with 10-year OS.
Yilmaz et al. (2020)	1-year mortality	No significant association with 1-year mortality.
Zhuang et al. (2022)	QoL, OS	Significant decrease in all scales of EORTC QLQ-C30 (intergroup p < 0.05) and significantly associated with poorer OS (HR: 1.088; 95% CI: 1.002-1.181).
Bakir et al. (2025)	Frailty	Significantly associated with higher frailty preoperatively, postoperatively and 30-days postoperatively (p = 0.001; p < 0.001; p < 0.001, respectively).
Kim et al. (2022)	12-, and 24-week survival	Significantly associated with worse 12- and 24-weeks survival (both p < 0.01).

Data in the 'findings' column include p-values and effect measures such as HR and OR. Abbreviations: CI, confidence interval; HR, hazard ratio; NS, not significant; OR, odds ratio; EFS, event-free survival; EORTC QLQ-C30, European Organization for Research and Treatment of Cancer Quality of Life Questionnaire; GHS, global health status; HRQoL, health-related quality of life; KPS, Karnofsky Performance Status; K-ESAS, Korea-Edmonton Symptom Assessment Scale; LOHS, length of hospital stay; LOS, length of stay; MUAC, mid-upper arm circumference; N+, node-positive; N-, node-negative; NLR, neutrophil-to-lymphocyte ratio; OS, overall survival; PN, parenteral nutrition.

Survival, mortality, and relapse

Across studies, associations between MUAC and survival-related outcomes were mixed. Movahed et al. (21) reported a significant association, in patients with oesophageal cancer, between lower baseline MUAC and 1-year mortality ($p = 0.013$). In contrast, Yilmaz et al. (22) found no significant association between low MUAC and 1-year mortality in patients with haematologic malignancies. Hou et al. (23) described no consistent association with cancer mortality overall, although each centimetre increase in MUAC corresponded with an 8% reduction in mortality risk (HR: 0.92, 95% CI: 0.87 - 0.96). Similarly, Viani et al. (24) observed no significant association with 10-year overall survival (OS).

Regarding early survival, Kim et al. (19) demonstrated a significant association between lower MUAC and worse 12- and 24-week survival in a palliative care setting (both $p < 0.01$). Zhuang et al. (18) also found a significantly poorer OS among patients with lower MUAC (HR: 1.088; 95% CI: 1.002-1.181).

For event-free survival (EFS), Schoeman et al. (25) reported significantly worse 2- and 3-year EFS in paediatric patients with low MUAC ($p = 0.049$ and $p = 0.030$, respectively), while associations with overall survival (OS) and 1-year EFS were non-significant.

Concerning relapse, Guzmán-León et al. (26) reported no significant impact of low MUAC on 3-year survival or relapse. However, higher MUAC was borderline significantly associated with a decrease in relapse risk (HR: 0.85; 95%CI: 0.73 to 1.00; $p = 0.049$).

Chemotherapy-related complications and toxicity

Studies examining chemotherapy-related toxicities showed inconsistent associations with MUAC. Draper et al. (27) observed a higher frequency ($p = 0.032$) and longer duration ($p = 0.001$) of neutropenia in paediatric patients with low MUAC receiving chemotherapy. Similarly, Simarmata et al. (17) identified significant associations between low MUAC and increased median frequency of febrile neutropenia ($p = 0.04$), longer length of hospital stay ($p = 0.001$), and prolonged induction phase ($p = 0.046$), while remission status showed no significant association.

In contrast, Salifu et al. (28) found a significantly lower risk of neutropenia among patients with higher MUAC (HR: 0.29; $p=0.045$), whereas associations with anaemia, thrombocytopenia, febrile neutropenia, mucositis, and death were non-significant.

Postoperative complications and length of hospital stay

Associations between MUAC and postoperative outcomes were heterogeneous. Eu et al. (29) demonstrated that low MUAC was associated with a 4.75-fold increased risk of infectious complications ($p = 0.016$) and a 5.00-fold increased risk of non-infectious complications ($p = 0.018$). Conversely, Leandro-Merhi et al. (30) found no significant associations between MUAC and postoperative complications, length of hospital stay (LOHS), or death.

Pedro et al. (31) reported no significant association with length of stay (LOS), and Swain et al. (32) found no association between MUAC and the duration of postoperative parenteral nutrition.

Quality of life and functional status

Low MUAC was consistently linked to poorer quality of life (QoL) and functional outcomes. Zhuang et al. (18) observed significant reductions across all domains of the EORTC QLQ-C30 among patients with lower MUAC (intergroup $p < 0.05$). Lu Shin et al. (33) reported significantly lower global health status (GHS) ($p = 0.014$) but higher cognitive functioning ($p = 0.048$) in patients with lower MUAC.

Regarding functional status, Jung et al. (20) found in a palliative setting significantly worse Karnofsky Performance Status (KPS) ($p < 0.001$) and significantly worse scores in six of ten symptom domains of the Korean-Edmonton Symptom Assessment Scale (K-ESAS): pain ($p = 0.001$), fatigue ($p = 0.001$), nausea ($p = 0.001$), drowsiness ($p = 0.002$), loss of appetite ($p < 0.001$) and feelings of wellbeing ($p = 0.032$). Bakir et al. (34) further demonstrated that lower MUAC was significantly associated with higher frailty scores at all assessed timepoints: preoperatively ($p = 0.001$), postoperatively ($p < 0.001$), and at 30 days postoperatively ($p < 0.001$).

Other clinical indicators

Arora et al. (35) found that pretreatment median neutrophil-to-lymphocyte ratio (NLR) was significantly higher in node-positive patients ($p = 0.001$), although post-treatment associations and associations within node-negative patients were non-significant.

Certainty of evidence

Although a GRADE assessment was planned in the PROSPERO protocol, it was not conducted because the included studies investigated heterogeneous and non-overlapping clinical outcomes. No other deviations from the registered protocol occurred during the conduct of this review.

Discussion

This systematic review synthesised evidence on the association between MUAC and various clinical outcomes in cancer patients. The findings suggest that lower MUAC is frequently associated with poorer outcomes, including survival, chemotherapy-related toxicity, postoperative complications, functional status, and quality of life. To our knowledge, this is the first review to specifically evaluate the prognostic value of MUAC in oncology. Most included studies were published after 2020, reflecting the growing interest in the clinical relevance of MUAC in oncology.

These associations are biologically plausible, as cancer-related malnutrition is a well-established contributor to poorer prognosis and impaired treatment tolerance. MUAC, as a simple indicator of peripheral muscle mass, may reflect this underlying vulnerability.

Nonetheless, the evidence identified in this review was heterogeneous. The included studies varied in cancer type, treatment modality, patient age, timing of MUAC measurement, and the cut-off values used. Adult MUAC thresholds were generally low, and sex-specific cut-offs were rarely applied, limiting comparability and thereby highlighting the need for standardised values in oncology.

The omission of the planned GRADE assessment represents a limitation of this review. No single clinical outcome was consistently evaluated across studies, and reported associations were highly variable, making formal certainty assessment inappropriate. Findings were therefore synthesized narratively, with methodological quality assessed using the CASP tool.

Most studies were conducted in non-Western or developing countries, underscoring the need for additional research in Western populations to enhance generalisability. Overall methodological quality ranged from moderate to high, with prospective and multicentre studies providing the most robust evidence. Common limitations included observational designs, small sample sizes, and incomplete adjustment for potential confounders. The heterogeneity in study design and outcome reporting suggests that non-significant findings do not necessarily imply the absence of an effect.

Despite these limitations, the evidence collectively highlights MUAC as a simple, low-cost, and potentially valuable anthropometric tool for assessing nutritional status and predicting clinical outcomes in oncology. Future research should focus on large, well-designed multicentre prospective studies to clarify whether changes in MUAC over time are associated with mortality, morbidity, treatment tolerance, and quality of life. Standardising MUAC cut-offs, including sex-specific thresholds, and harmonising measurement timing would further improve comparability and support its integration into routine clinical practice.

In conclusion, MUAC appears to be a promising, clinically relevant measure in oncology. However, further high-quality evidence is needed to clarify its predictive value and guide its integration into routine patient care.

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BELGISCHE VOEDSELCONSUMPTIEPEILING 2014

VOEDSELFREQUENTIEVRAGENLIJST

Adolescenten en Volwassenen

Deze vragenlijst peilt naar jouw consumptie van verschillende voedingsmiddelen gedurende de laatste 12 maanden.

Geselecteerde persoon

Nummer van de persoon :

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Voornaam.....

Enquêteur

Nummer van de enquêteur :

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Datum van de enquête

		/			/				
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Hoe deze vragenlijst invullen ?

Antwoord zelf op de vragen. Duid **slechts één keuze** aan voor elke vraag.

Lees elke vraag en antwoordmogelijkheden zeer aandachtig alvorens te antwoorden.

Deze voedselfrequentievragenlijst geeft ons een beeld van uw voedingsinname over een langere periode. Daarom gaan alle vragen over uw **gemiddelde** voedingsinname **tijdens de laatste 12 maanden**. Houd hier rekening mee bij het beantwoorden van de vragen.

Duid in de tabellen op de volgende pagina's aan hoe vaak u de vermelde producten eet door **het vakje aan te kruisen dat het meest van toepassing is op u**.

OPGELET: Deze vragenlijst is opgesteld om gelezen en gecodeerd te worden door een scanner. Het is dus belangrijk dat u een zichtbaar en duidelijk kruis plaatst in het vakje. In het geval u een fout maakt, gelieve het foutieve antwoord zo duidelijk mogelijk te doorstrepen.

Ter verduidelijking werd een voorbeeld uitgewerkt :

Voorbeeld 1: U eet nooit andijvie.

Voorbeeld 2: U eet in het seizoen (mei-juni) ongeveer 2 maal per week asperges.
Als u dit over een heel jaar bekijkt, komt dit neer op een gemiddelde van 8 tot 10 maal per jaar.
U kruist het vakje "Minder dan 1 dag per maand" aan.

Voorbeeld 3: U eet gemiddeld om de twee dagen een appel.
U kruist het vakje "2 - 4 dagen per week" aan.

	Gemiddelde consumptie in de afgelopen 12 maanden								
Aantal keer	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
01. Andijvie	☒	☐	☐	☐	☐	☐	☐	☐	☐
02. Asperges	☐	☒	☐	☐	☐	☐	☐	☐	☐
03. Appels	☐	☐	☐	☐	☒	☐	☐	☐	☐

Het algemene voedingspatroon

FFQ.01. In de onderstaande tabel zijn een hele reeks voedingsmiddelen opgesomd. Probeer (zo exact mogelijk) weer te geven hoe vaak u de opgesomde producten eet of drinkt. Denk hierbij aan het gemiddelde in de laatste 12 maanden.

DRANKEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3
01. Water	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
02. Koffie, thee en dergelijke (chicorei, kruidenthee)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
03. Fruitsap, groentesap	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
04. Light frisdranken	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
05. Gesuikerde frisdranken	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
06. Sportdranken (Isostar, Aquarius)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
07. Energiedranken (Redbull, Burn, Monster)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
08. Energiedrank in combinatie met alcohol (Vodka-Redbull,)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
09. Wijn (ook champagne en schuimwijn)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
10. Bier	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
A : Met alcohol	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B : Alcoholvrij	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
11. Sterke dranken (whisky, cognac)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
12. Alcoholische cocktails (mojito, cosmopolitan en aperitieven (Porto)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
13. Sojadrink	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
14. Rijstdrank, haverdrank, amandel-drink	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
15. Probiotisch verrijkte dranken (Actimel, Yakult, Bifidus,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

AARDAPPELEN EN GRAANPRODUCTEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
16. Wit brood en/of witte broodproducten (rozijnenbrood, suikerbrood...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
17. Bruin brood en/of volkorenbrood (multigranenbrood)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
18. Ontbijtgranen									
A: Volkoren (Special K ...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B: Niet volkoren (Cornflakes, Chocopops)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
19. Patisserie, koffiekoeken (fruittaartje, eclair, slagroomtaart, croissant,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
20. Gekookte of gestoomde aardappelen, aardappelpuree	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
21. Rijst									
A: Witte rijst	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B: Bruine rijst	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
22. Pasta, deegwaren									
A: Witte pasta,	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B: Volkoren	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
23. Quinoa, couscous, bulghur	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

MELK- EN CALCIUMVERRIJKTE PRODUCTEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
24. Melk (ook karnemelk)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
25. Gearomatiseerde melk (chocolademelk, aardbeienmelkdrink,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
26. Pudding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
27. Yoghurt, platte kaas gesuikerde verse kaas (Petit Gervais,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
28. Kaas (geen platte kaas)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

FRUIT

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
29. Vers fruit	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
30. Diepgevroren fruit, fruit in blik of plastic potjes.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
31. Gedroogd fruit (rozijnen, abrikozen, vijgen) en gekonfijt fruit	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

GROENTEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
32. Verse rauwe groenten	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
33. Zelfbereide verse groenten (niet rauw)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
34. Bereide groenten (blik, bokaal, diepvries,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
35. Algen (zeewier, nori,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

VLEES, VIS, EIEREN EN VERVANGPRODUCTEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
36. Gevogelte (kip, kalkoen,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
37. Koe (rund)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
38. Paard	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
39. Varken	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
40. Konijn en wild (fazant, hert,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
41. Orgaanvlees (lever, niertjes,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
42. Vleesbereidingen (worst, hamburger...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
43. Vleeswaren									
A. Magere (ham kipfilet, filet de saxe, rosbief, kippenham)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B. Vette (salami, paté, hespenworst,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
44. Salades met mayonaise (vis-, vleesgroenten-, garnaalsalade,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
45. Verse of diepgevroren vis	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
46. Gerookte vis (gerookte zalm, heilbot, makreel, forel,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
47. Schaal- en schelpdieren (mosselen, oesters kreeft, krab, garnalen)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
48. Vegetarische producten (tofu, quorn, tempe, seitan,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
49. Eieren	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
50. Peulvruchten (bonen, linzen, ...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

KANT- EN KLARE MAALTIJDEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
51. Commercieel bereide maaltijden (diepvries of frigo) (lasagne, pizza,...) Aangekocht in de supermarkt, traiteur, slager, enz...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

SNOEPGOED, (ZOETE) TOESPIJS EN NOTEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
52. Chips	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
53. Noten (amandelnooten, borrelhapnootjes, pindanoten,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
54. Zaden (zonnebloempitten, sesamzaden, pijnboompitten, ...) zadenpasta (sesampasta,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
55. IJs	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
56. Snoep en chocolade	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
57. Droge koeken, cake	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
58. Toespijs (chocopasta, confituur, speculoospasta,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
59. Pindakaas	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

SAUZEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1 keer	2 - 3 keer	Meer dan 3 keer
60. Sauzen op basis van plantaardige oliën (mayonaise, tartaarsaus, andalousesaus, dressings)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
61. Ketchup	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

HET ZOETEN VAN VOEDINGSMIDDELEN

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
62. Suiker (kristal-, riet, kandijnsuiker, honing, cassonade,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
63. Intensieve kunstmatige zoetstoffen (canderel, aspartaam, sucralose,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
64. Zoetstof uit stevia	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
65. Tagatesse	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

GEFRITUURDE VOEDINGSMIDDELEN

FFQ.02. Hoe vaak eet u volgende gefrituurde voedingsmiddelen? Denk hierbij aan het gemiddelde in de laatste 12 maanden.

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
01. Friten	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
02. Aardappelkroket en andere gefrituurde aardappelproducten	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
03. Gefrituurde kaas-, vlees of visbereidingen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
04. Appelbeignets	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
05. Gefrituurde groenten (uienringen,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

VETSTOFFEN

FFQ.03. Hoe vaak gebruikt u volgende vetstoffen om te koken? Denk hierbij aan het gemiddelde in de laatste 12 maanden.

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
01. Margarine/minarine	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
02. Boter, reuzel, smout	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
03. Olie (olijf-, zonnebloem-, koolzaad, maïsolie,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

RAUWE VOEDINGSMIDDELEN

FFQ.04. Hoe vaak eet u volgende rauwe voedingsmiddelen? Denk hierbij aan het gemiddelde in de laatste 12 maanden.

Gemiddelde consumptie in de afgelopen 12 maanden									
	NOOIT	PER MAAND		PER WEEK			PER DAG		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	1keer	2 - 3 keer	Meer dan 3 keer
01. Sushi	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
02. Steak tartaar, rauw gehakt en preparé	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
03. Verse melk van de boerderij	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
04. Zelfgemaakte mayonaise (op basis van rauwe eieren,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
05. Zachte kaas op basis van rauwe melk (Brie, Camembert...)									
A: Industrieel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
B: Van de boerderij	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9
06. Dessert met rauwe eieren (chocolademousse, tiramisu,...)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9

VOEDINGSSUPPLEMENTEN

FFQ.05. Hebt u in de laatste 12 maanden voedingssupplementen ingenomen?

- ☐ Nee -> Ga naar het einde.
☐ Ja, in de winter -> Ga naar FFQ.06.
☐ Ja, in de rest van het jaar -> Ga naar FFQ.07.

FFQ.06. Welke voedingssupplementen hebt u ingenomen en hoe vaak? Duid aan waar u de voedingssupplementen gekocht hebt.

	NOOIT	PER MAAND		PER WEEK			PER DAG	PLAATS AANKOOP		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	Elke dag	Winkel	Internet	Apotheek
01. Vitamine A	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
02. Vitamine A&D	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
03. Vitamine B	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
04. Vitamine C	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
05. Vitamine D	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
06. Vitamine E	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
07. Vitamine K	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
08. Multi-vitaminen zonder mineralen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
09. Multi-vitaminen & mineralen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
10. Beta-caroteen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
11. Omega 3	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
12. Calcium	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
13. Ginkgo	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
14. Ijzer	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
15. Fluor	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
16. Andere	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3

FFQ.07. Welke voedingssupplementen hebt u ingenomen en hoe vaak? Duid aan waar u de voedingssupplementen gekocht hebt.

	NOOIT	PER MAAND		PER WEEK			PER DAG	PLAATS AANKOOP		
		Minder dan 1 keer	1 - 3 keer	1 keer	2 - 4 keer	5 - 6 keer	Elke dag	Winkel	Internet	Apotheek
01. Vitamine A	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
02. Vitamine A&D	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
03. Vitamine B	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
04. Vitamine C	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
05. Vitamine D	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
06. Vitamine E	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
07. Vitamine K	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
08. Multi-vitaminen zonder mineralen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
09. Multi-vitaminen & mineralen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
10. Beta-caroteen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
11. Omega 3	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
12. Calcium	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
13. Ginkgo	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
14. Ijzer	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
15. Fluor	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3
16. Andere	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 1	☐ 2	☐ 3

Bedankt voor uw tijd om deze vragenlijst in te vullen. Uw antwoorden zullen worden samen- gevoegd met de antwoorden van alle andere deelnemers. Deze informatie zal gebruikt worden om voor België een effectiever voedingsbeleid te ontwikkelen en nieuwe voedingsaanbevelingen te formuleren.

Indien u opmerkingen of bedenkingen heeft, gelieve deze in het onderstaande kader te noteren:

Indien u vragen heeft of bijkomende informatie wenst, aarzel niet contact op te nemen

met : Mevr. Sarah Bel
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De eerste afbeelding werd overgenomen van wikiHow (<https://www.wikihow.com/Measure-Mid-Arm-Circumference>).
De overige afbeeldingen werden overgenomen van International Society for the Advancement of Kinanthropometry (ISAK).

Vragenlijst dieetveranderingen

Heeft u uw voedingspatroon sinds het vernemen van uw diagnose aangepast?

- Ja/ nee
- Zo ja, sinds wanneer?
 - Sinds het tijdstip van diagnose
 - Sinds de start van de behandeling
 - Tijdens de behandeling (specifiek wanneer: ...)
 - Ik weet het niet
 - Anders, namelijk:
- Zo ja, was dit een bewuste keuze?
 - Ja
 - Nee
 - Gedeeltelijk (toelichting: ...)
- Zo ja, welke aanpassingen heeft u gedaan aan uw voedingspatroon?
 - Ik eet minder/ even veel/ meer dan voordien.
 - Ik vermijd bepaalde zaken: (welke)
 - Omdat:
 - Ik er nu minder naar verlang.
 - Ik ze niet meer kan verdragen (te felle smaak/ reuk of juist afwezig?, misselijkheid/braken door chemo?)
 - Ik denk dat dit mijn verdere gezondheid ten goede zal komen.
 - Het fysiek voor mij te zwaar wordt om eten klaar te maken/ naar de winkel te gaan.
 - Ik hierdoor geconstipeerd geraak.
 - Ik hierdoor frequent diarree heb.
 - Ik heb moeite met kauwen of slikken.
 - Dit mij aangeraden werd door mijn behandelend team.
 - ...
 - Ik heb bepaalde zaken toegevoegd aan mijn dieet: (welke)
 - Omdat:
 - Ik er nu meer dan voordien naar verlang.
 - Ik denk dat ze mijn verdere gezondheid ten goede zullen komen.
 - Dit mij aangeraden werd door mijn behandelend team.
 - ...

Hoe vaak consumeerde u alcohol **voor uw diagnose?** (enkel tijdens eerste contactmoment)

- Ik drink geen alcohol
- Minder dan eenmaal per week
- 1-2 keer per week

- 3-4 keer per week
- 5-6 keer per week
- Dagelijks
- ...

Op dagen dat u alcohol consumeerde, hoeveel (standaard)eenheden dronk u gemiddeld **voor uw diagnose?** (enkel tijdens eerste contactmoment)

- 1-2 eenheden
- 3-4 eenheden
- Meer dan 5 eenheden

Heeft u aanpassingen gedaan aan uw alcoholgebruik sinds uw diagnose of sinds het vorige contactmoment?

- Ja/nee
- Zo ja, hoe is dit veranderd?
 - Ik drink minder alcohol dan vroeger
 - Ik drink meer alcohol dan vroeger
 - Ik volledig gestopt met alcohol te drinken
 - ...
- Zo ja, was dit een bewuste beslissing?
 - Ja/nee
 - Zo ja, waarom?
 - Omwille van medisch advies
 - Ik verdraag het minder goed
 - Ik denk dat het beter is voor mijn gezondheid
 - Omwille van financiële redenen
 - Andere: ...

Hoe vaak consumeert u alcohol **op dit moment?**

- Ik drink geen alcohol
- Minder dan eenmaal per week
- 1-2 keer per week
- 3-4 keer per week
- 5-6 keer per week
- Dagelijks
- ...

Op dagen dat u alcohol drinkt, hoeveel (standaard)eenheden drinkt u dan gemiddeld?

- 1-2 eenheden
- 3-4 eenheden
- Meer dan 5 eenheden

Rookte u op het moment van diagnose? (enkel tijdens het eerste contactmoment)

- Ja/nee
- Zo ja, hoeveel rookte u voor uw diagnose?
 - Af en toe (minder dan eenmaal per week)
 - 1-2 keer per week
 - 3-4 keer per week
 - 5-6 keer per week
 - Dagelijks
 - ...
- Zo ja, hoeveel sigaretten (of vergelijkbare alternatieven) rookte u gemiddeld per dag voor uw diagnose?
 - 1-5 sigaretten
 - 6-10 sigaretten
 - 11-20 sigaretten
 - Meer dan 20 sigaretten
- Zo ja, hoeveel jaar rookte u?
 - ...

Heeft u uw rookgedrag aangepast sinds uw diagnose of sinds het vorige contactmoment?

- Ja/nee
- Zo ja, op welke manier?
 - Ik rook minder dan voor mijn diagnose.
 - Ik rook meer dan voor mijn diagnose.
 - Ik ben volledig gestopt met roken.
- Zo ja, waarom heeft u uw rookgedrag aangepast?
 - Omwille van medisch advies
 - Ik verdraag het minder goed
 - Ik denk dat het beter is voor mijn gezondheid
 - Uit financiële overweging
 - Door familiale redenen
 - ...

Hoeveel rookt u op dit moment?

- Nooit
- Af en toe (minder dan eenmaal per week)
- 1-2 keer per week
- 3-4 keer per week
- 5-6 keer per week
- Dagelijks

Hoeveel sigaretten (of vergelijkbare alternatieven) rookt u gemiddeld per dag?

- 0, ik rook niet
- 1-5 sigaretten
- 6-10 sigaretten
- 11-20 sigaretten
- Meer dan 20 sigaretten

Hoeveel fysieke activiteit beoefende u **voor uw diagnose?** (enkel eerste contactmoment)

- Nooit
- Minder dan eenmaal per week
- 1-2 keer per week
- 3-4 keer per week
- 5 of meer keer per week

Hoe lang duurde elk moment van fysieke activiteit gemiddeld **voor uw diagnose?** (enkel eerste contactmoment)

- Minder dan 15 minuten
- 15-30 minuten
- 30-60 minuten
- Meer dan 60 minuten

Is uw niveau van fysieke activiteit veranderd sinds uw diagnose of het vorige contactmoment?

- Ja/nee
- Zo ja, op welke manier?
 - o Ik beweeg meer dan vroeger.
 - o Ik beweeg minder dan vroeger.
 - o ...
- Waardoor is dit veranderd?
 - o Door moeheid
 - o Door tijdstekort
 - o Door pijn of fysieke beperking
 - o Om mijn gezondheid te verbeteren
 - o Om mijn sociaal leven te onderhouden/ te verbeteren
 - o ...

Hoe vaak beoefent u fysieke activiteit op dit moment?

- Nooit
- Minder dan eenmaal per week
- 1-2 keer per week
- 3-4 keer per week
- 5 of meer keer per week

Hoe lang duurt elk moment van fysieke activiteit gemiddeld?

- Minder dan 15 minuten
- 15-30 minuten
- 30-60 minuten
- Meer dan 60 minuten

Heeft u het gevoel over voldoende informatie te beschikken om geïnformeerde keuzes te maken omtrent uw voedingspatroon?

- Ja/nee

Indien ja, waar heeft u die informatie verkregen?

- Via mijn behandelend arts
- Via mijn huisarts
- Zelf online opgezocht
- Via vrienden of familie
- Via lotgenoten
- Via een nutritiecoach
- Via een diëtist
- ...

Indien nee, zou u hierover graag meer geïnformeerd worden?

- Ja/nee
 - o Follow-upvraag: indien ja, welke vorm van extra voedingsadvies zou u het meest aanspreken (via diëtiste? Extra van arts? Folder/brochure? App?)

Hoe tevreden bent u over de voedingsinformatie die u van uw behandelend team ontvangt?

- Score 1-5 (helemaal niet, niet, neutraal, tevreden, zeer tevreden)

In welke mate vindt u het belangrijk aandacht te besteden aan uw voedingspatroon in het dagelijks leven?

- Score 1-5

In welke mate vindt u het belangrijk aandacht te besteden aan uw voedingspatroon in uw huidige situatie?

- Score 1-5

Eet u vaak samen met anderen?

- Ja/nee

Heeft dit invloed op uw eetgewoonten?

- Ja/nee (zo ja, op welke manier: ...)

Is er nog iets anders dat u zou willen delen over uw eetgewoonten of -uitdagingen sinds het moment van uw diagnose?

...

Appendix 5: Home measurement instructions

Instructies voor het voedingsonderzoek UZ Gent

Wij adviseren om elke meting op een vaste dag in de week uit te voeren.

1) Metten van het gewicht op de weegschaal

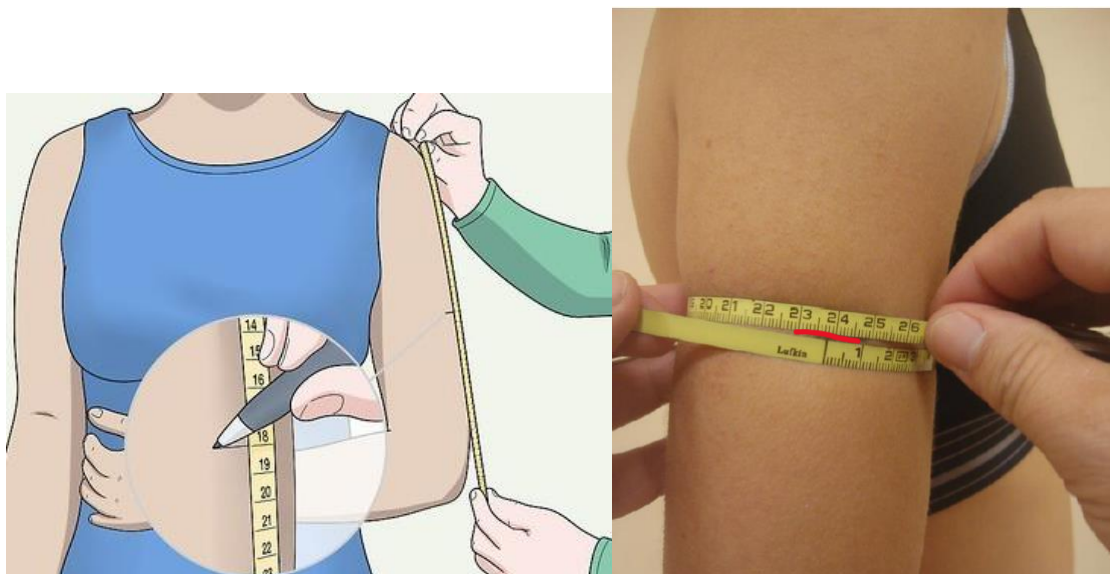
Wij adviseren u om uw gewicht wekelijks op een vast moment te meten (vb. steeds maandagochtend rond 8u). Dit gebeurt idealiter naakt in de ochtend, voor het ontbijt en na het toiletbezoek. Het is belangrijk dat u mooi rechtop en stabiel staat op de weegschaal. U mag het gewicht noteren in de meettabel met 1 cijfer na de komma (vb. 65,3 kg).

2) Metten van de bovenarmomtrek met het meetlint

Voor het meten van de bovenarmomtrek heeft u het meetlint nodig. Wij adviseren u om dit met twee te doen (vb. Met behulp van partner, kinderen, thuisverpleegkundige...). **De meting gebeurt steeds aan dezelfde arm.** Als u rechtshandig bent, kan u kiezen voor de linkerarm. Als u linkshandig bent, kan u kiezen voor uw rechterarm. De arm moet volledig ontbloot worden.

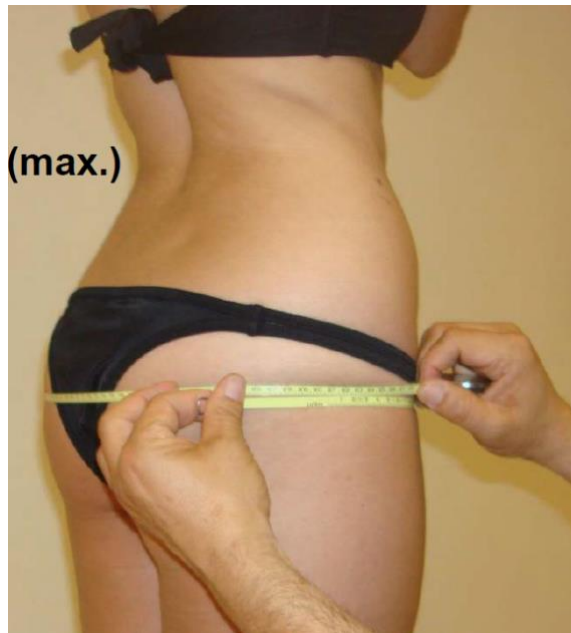
Het eerste dat u moet doen is het midden van uw bovenarm bepalen. Dit gebeurt door de afstand te meten tussen uw schouder top en elleboog (zie foto 1 voor meer informatie). Dit gebeurt met de elleboog geplooid in 90° en best in staande houding, mooi rechtop. Het midden van deze afstand is de plaats waar u de bovenarmomtrek zal meten en markeert u best met een streepje.

Nadien laat u uw arm ontspannen naast het lichaam hangen, ook in staande houding. U brengt het meetlint aan ter hoogte van de markering en hierbij is het belangrijk om de nulwaarde net onder het streepje te leggen en het andere deel van het meetlint boven de markering te plaatsen (zie foto 2 voor verduidelijking). Het meetlint moet de bovenarm goed omvatten maar mag zeker niet te strak zitten. U noteert de waarde met 1 cijfer na de komma in de meettabel (vb. 30,4 cm).



3) Meten van de heupomtrek met het meetlint

Voor het meten van de heupomtrek heeft u het meetlint nodig. Wij adviseren u om dit met twee te doen, maar dit kan ook alleen gebeuren. Dit gebeurt in rechtop staande houding zonder broek (ondergoed mag wel aanblijven). U brengt het meetlint aan ter hoogte van het breedste deel van uw billen (zie foto voor verduidelijking). U noteert de waarde in centimeter met 1 cijfer na de komma in de meettabel.



4) Meten van de taille

Voor het meten van de tailleomtrek heeft u het meetlint nodig. Wij adviseren u om dit met twee te doen, maar dit kan ook alleen gebeuren. Dit gebeurt in rechtop staande houding zonder broek (ondergoed mag wel aanblijven). U brengt het meetlint aan net onder de ribben ter hoogte van de zijkant van uw lichaam/ flank (zie foto voor verduidelijking). U noteert de waarde in centimeter met 1 cijfer na de komma in de meettabel op het einde van de rustige uitademing.



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In Vulformulier wekelijkse thuismetingen

We willen u vragen om de metingen die u wekelijks thuis uitvoert in onderstaande tabel bij te houden. Dit doet u zoals aangegeven in onderstaand voorbeeld. Gelieve deze mee te brengen naar de contactmomenten. Bij vragen of onduidelijkheden mag u ons steeds contacteren via emiel.demoertoose@ugent.be of mathilde.majchrzak@ugent.be.

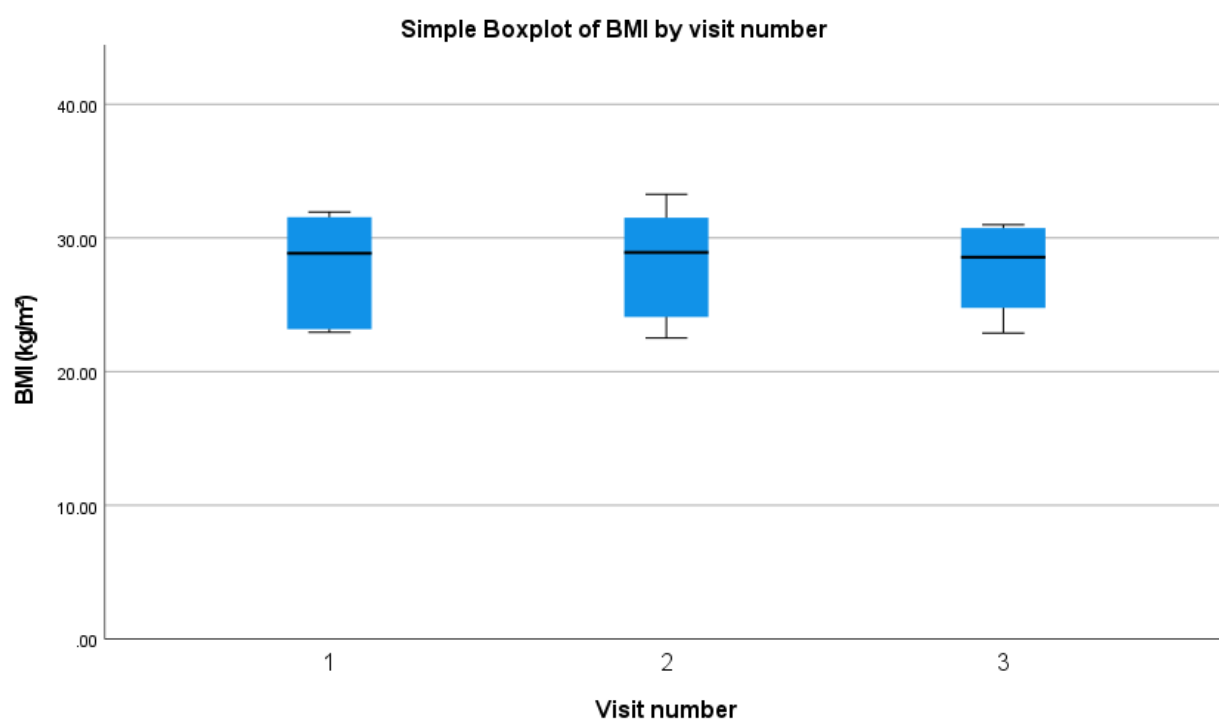
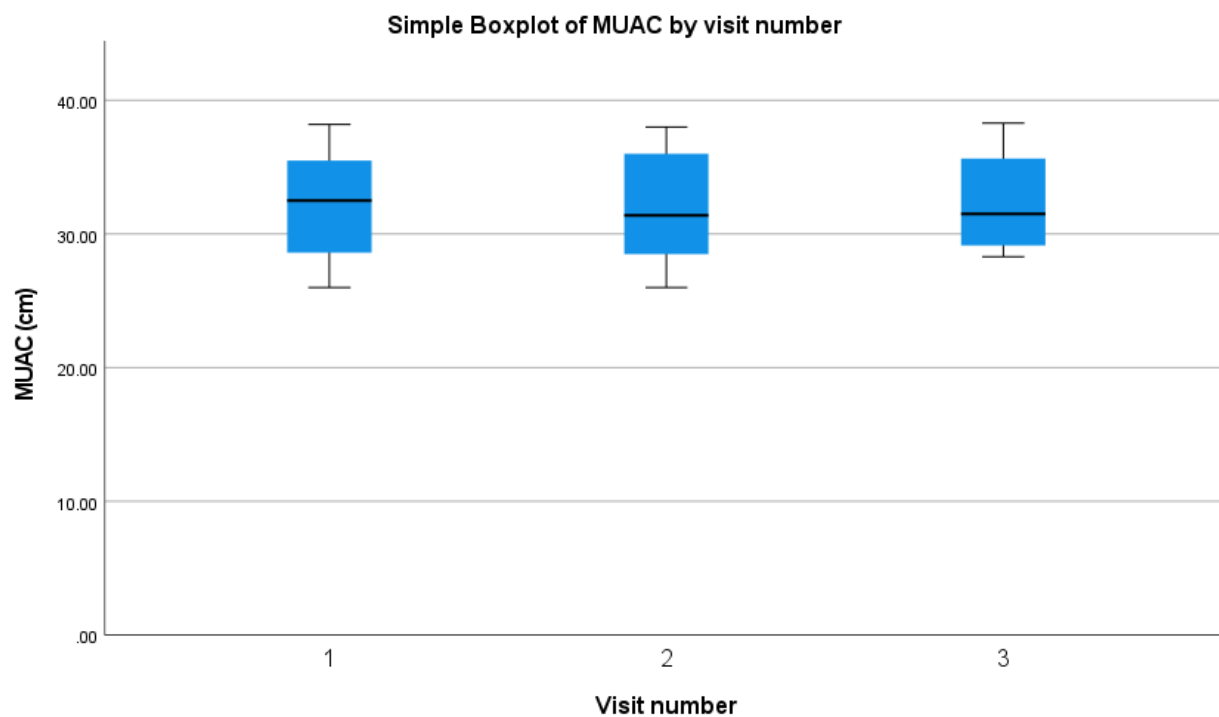
[illegible]

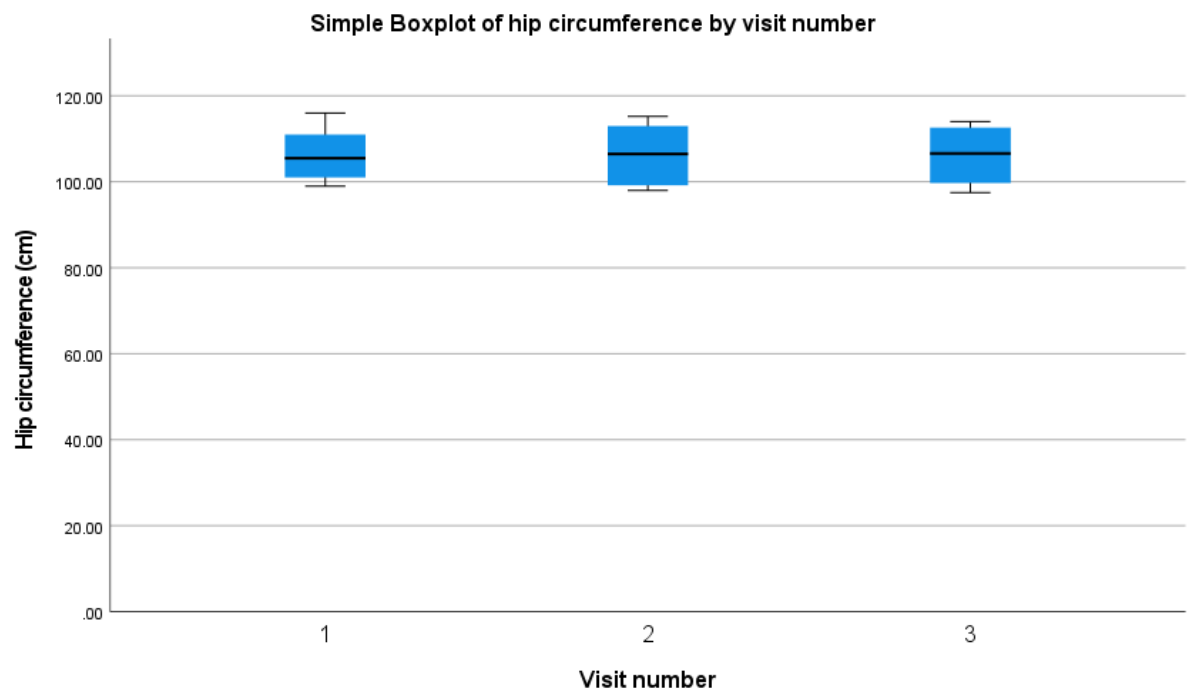
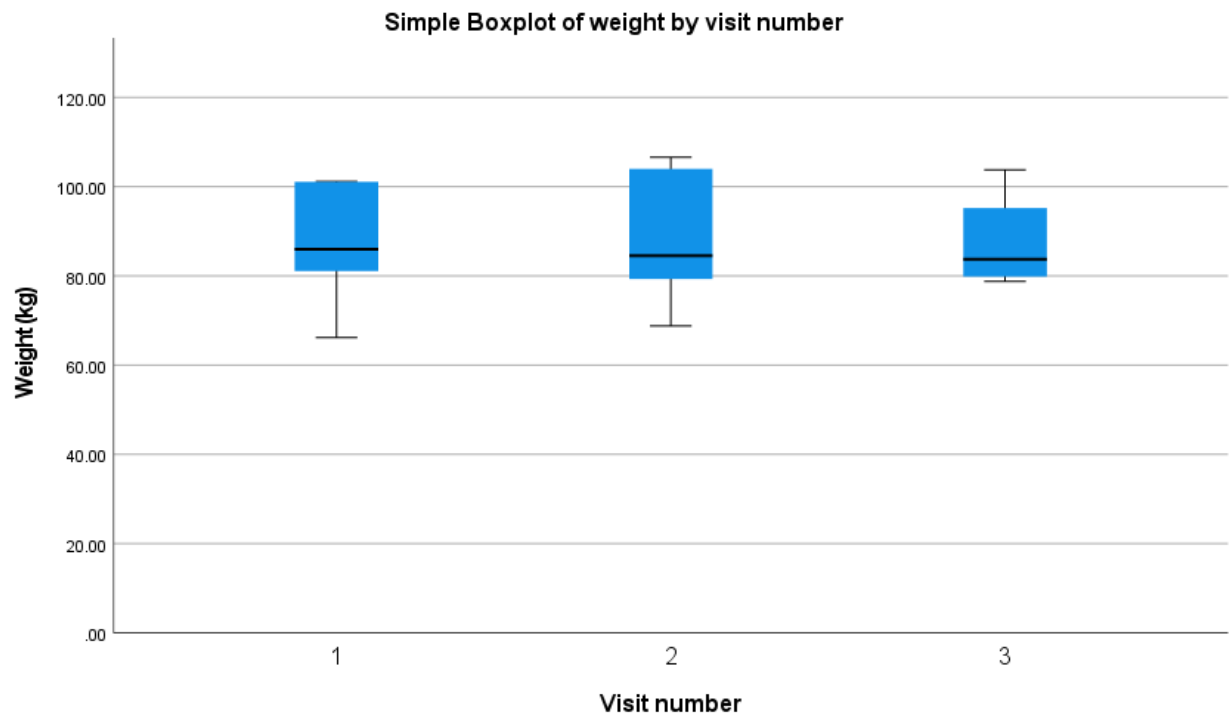
Appendix 7: Evolution of anthropometric measurements during treatment

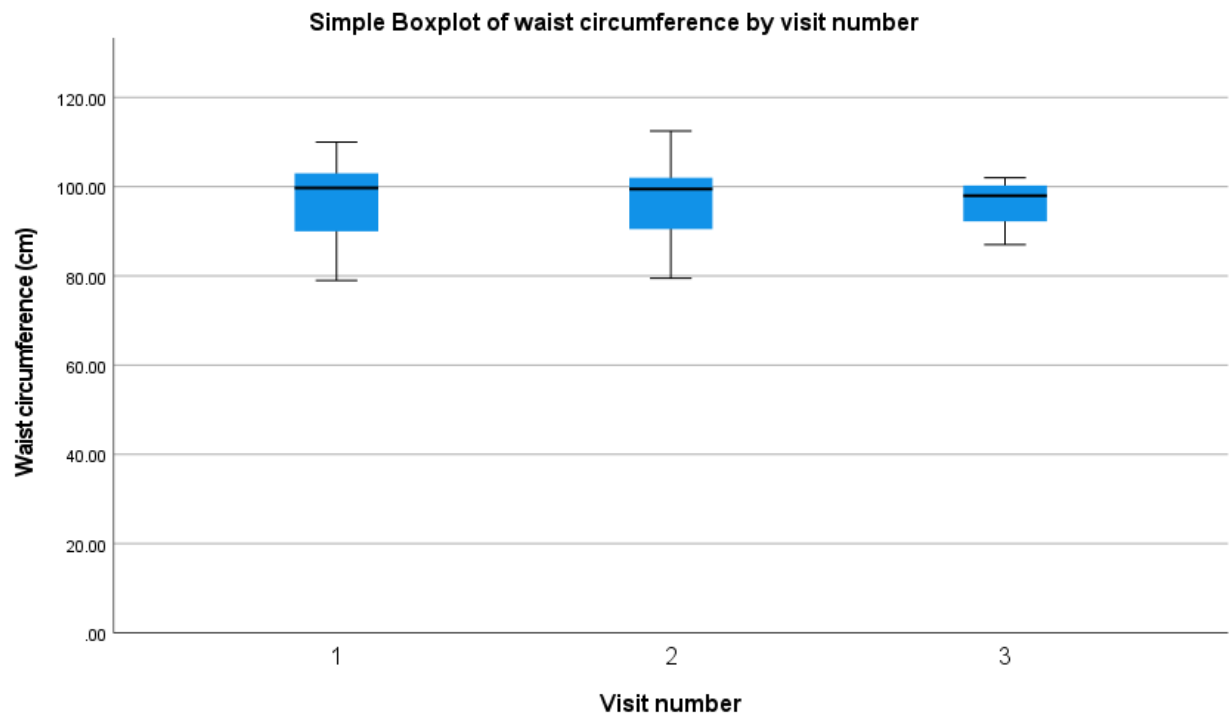
Anthropometric measurements	Visit 2 (Mid) (n=6)	Visit 3 (End) (n=4)	Δ Visit 1 $\rightarrow$ 2 (n=6)	Δ Visit 2 $\rightarrow$ 3 (n=4)	Δ Visit 1 $\rightarrow$ 3 (n=4)
MUAC, cm (mean $\pm$ SD)	31.9 $\pm$ 4.8	32.4 $\pm$ 4.4	-0.3 $\pm$ 0.7 (-1.0%)	0.1 $\pm$ 1.1 (0.3%)	-0.6 $\pm$ 1.7 (-1.5%)
Weight, kg (mean $\pm$ SD)	88.0 $\pm$ 15.0	87.5 $\pm$ 11.3	1.0 $\pm$ 3.0 (1.1%)	-0.6 $\pm$ 1.7 (-0.6%)	-1.1 $\pm$ 2.9 (-1.3%)
BMI, kg/m² (mean $\pm$ SD)	28.2 $\pm$ 4.4	27.8 $\pm$ 3.8	0.3 $\pm$ 1.0 (1.1%)	-0.2 $\pm$ 0.6 (-0.6%)	-0.4 $\pm$ 1.0 (-1.3%)
Hip circumference, cm (mean $\pm$ SD)	106.4 $\pm$ 7.8	106.2 $\pm$ 7.7	0.1 $\pm$ 3.3 (0.0%)	0.2 $\pm$ 1.0 (0.1%)	-0.8 $\pm$ 2.9 (-0.8%)
Waist circumference, cm (mean $\pm$ SD)	97.3 $\pm$ 11.2	96.3 $\pm$ 6.5	0.3 $\pm$ 1.9 (0.4%)	-1.6 $\pm$ 1.7 (-1.7%)	-1.9 $\pm$ 2.8 (-1.9%)
Waist-to-hip ratio (mean $\pm$ SD)	0.91 $\pm$ 0.08	0.91 $\pm$ 0.06	0.00 $\pm$ 0.01 (0.4%)	-0.02 $\pm$ 0.02 (-1.9%)	-0.01 $\pm$ 0.01 (-1.1%)

Visit 1: 1-2 weeks post-diagnosis, prior to the initiation of treatment. Visit 2: Mid-treatment. Visit 3: 1-2 weeks prior to surgical resection, following the completion of neo-adjuvant treatment. Values are presented as mean $\pm$ SD. Absolute change (Δ) is shown with relative change (%) in parentheses. Abbreviations: SD, standard deviation; BMI, body mass index; MUAC, mid-upper arm circumference.

Appendix 8a: Boxplots of anthropometric parameters used in the LMM analyses







Boxplots showing the distribution of MUAC, BMI, weight, hip, and waist circumference before running the linear mixed model analyses. Each boxplot displays the median, interquartile range and potential outliers. Abbreviations: MUAC, mid-upper arm circumference; BMI, body mass index.

Appendix 8b: Full SPSS output of the linear mixed models assessing the association between MUAC and other anthropometric parameters

BMI

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	10.449	1.840	.204
time	1	8.621	.821	.389
BMI	1	10.642	18.680	.001

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Estimates of Fixed Effects^a

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	7.841	5.781	10.449	1.356	.204	-4.965	20.646
time	-.184	.203	8.621	-.906	.389	-.645	.278
BMI	.876	.203	10.642	4.322	.001	.428	1.323

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Covariance Parameters

Estimates of Covariance Parameters^a

Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	.370	.179	2.071	.038	.144	.954
Intercept [subject= id] Variance	6.050	4.157	1.456	.146	1.574	23.257

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Weight

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	5.856	2.499	.166
time	1	8.892	.911	.365
weight	1	5.807	56.679	<.001

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Estimates of Fixed Effects^a

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	5.702	3.607	5.856	1.581	.166	-3.176	14.581
time	-.197	.206	8.892	-.954	.365	-.663	.270
weight	.306	.041	5.807	7.529	<.001	.205	.406

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Covariance Parameters

Estimates of Covariance Parameters^a

Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	.384	.184	2.094	.036	.151	.980
Intercept [subject= id] Variance	1.822	1.381	1.319	.187	.412	8.051

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Hip circumference

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	12.858	.000	.988
time	1	7.042	.492	.506
hip	1	12.800	7.875	.015

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Estimates of Fixed Effects^a

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	-.180	11.682	12.858	-.015	.988	-25.445	25.086
time	-.172	.246	7.042	-.701	.506	-.753	.408
hip	.306	.109	12.800	2.806	.015	.070	.541

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Covariance Parameters

Estimates of Covariance Parameters^a

Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	.543	.291	1.869	.062	.190	1.550
Intercept [subject = id] Variance	9.439	7.311	1.291	.197	2.069	43.075

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Waist circumference

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	9.896	1.576	.238
time	1	8.774	.097	.762
waist	1	10.033	2.695	.132

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Estimates of Fixed Effects^a

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	14.115	11.243	9.896	1.255	.238	-10.972	39.202
time	-.088	.281	8.774	-.312	.762	-.726	.550
waist	.187	.114	10.033	1.642	.132	-.067	.440

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Covariance Parameters

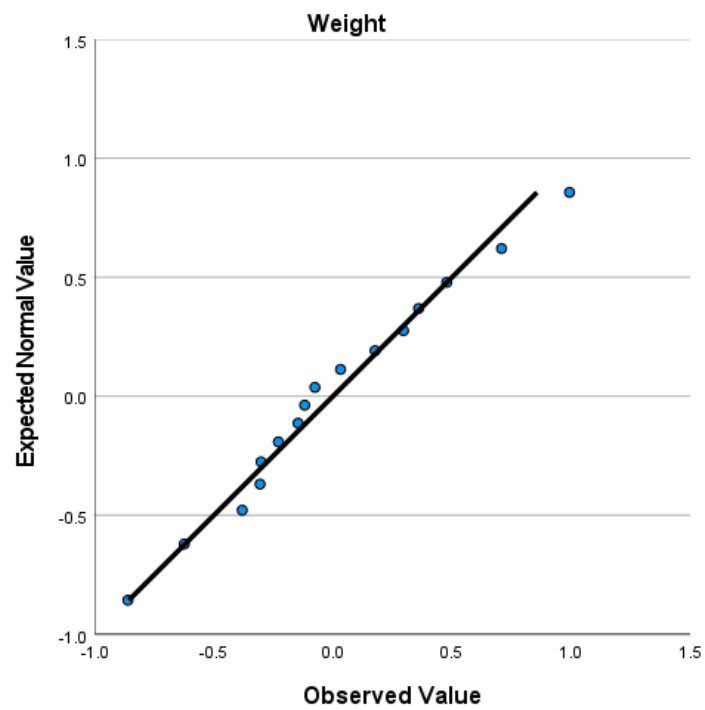
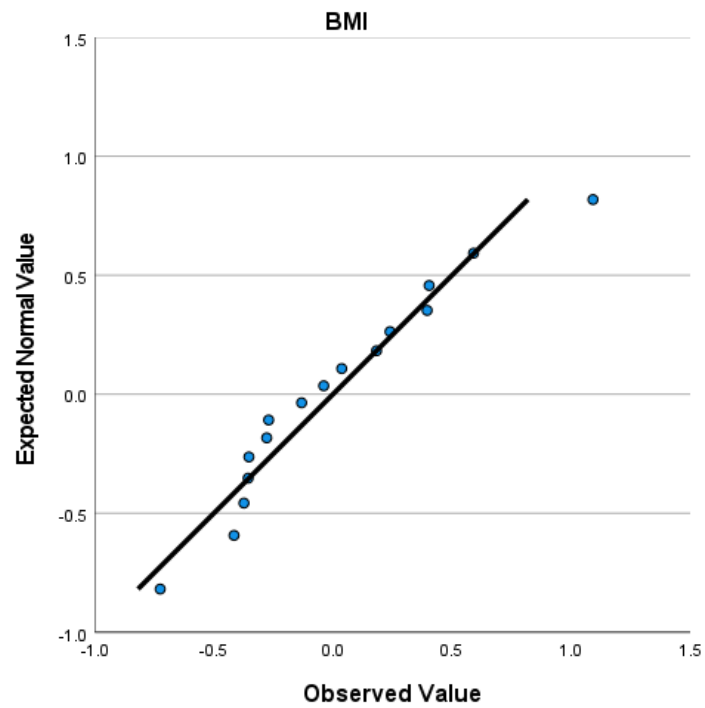
Estimates of Covariance Parameters^a

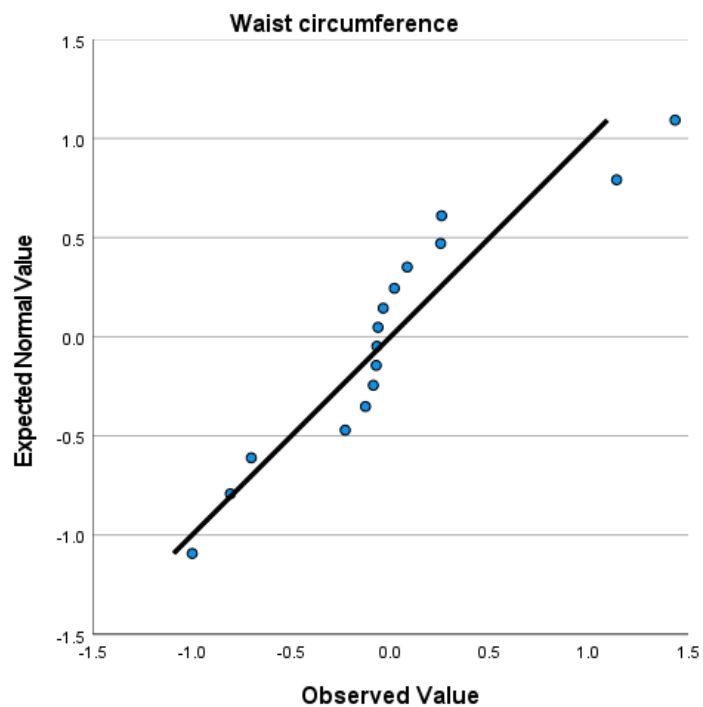
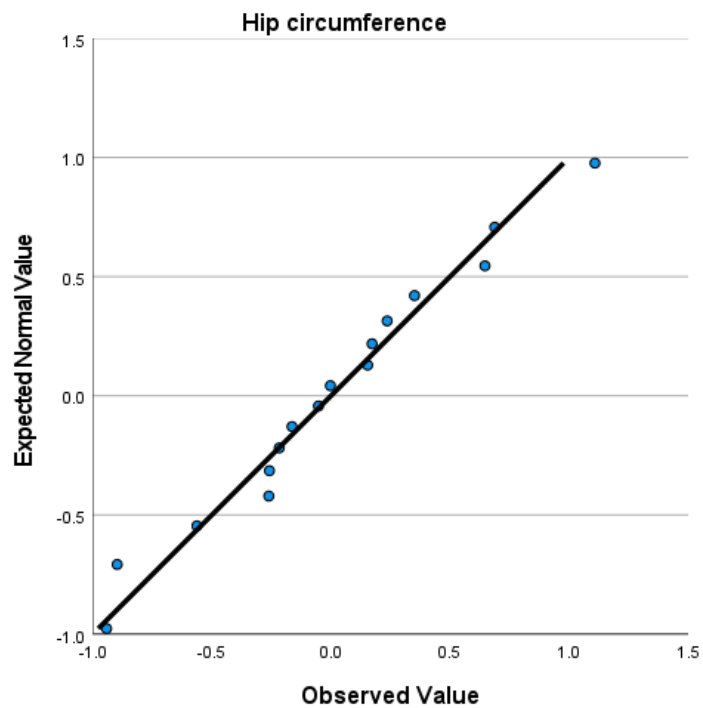
Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	.661	.332	1.994	.046	.247	1.767
Intercept [subject = id] Variance	13.617	10.026	1.358	.174	3.216	57.656

a. Dependent Variable: Mid-upper arm circumference (MUAC) (cm).

Each model includes one anthropometric parameter as fixed effect, with patient number as random intercept. The output presents type III tests of fixed effects, parameter estimates, and covariance parameters.

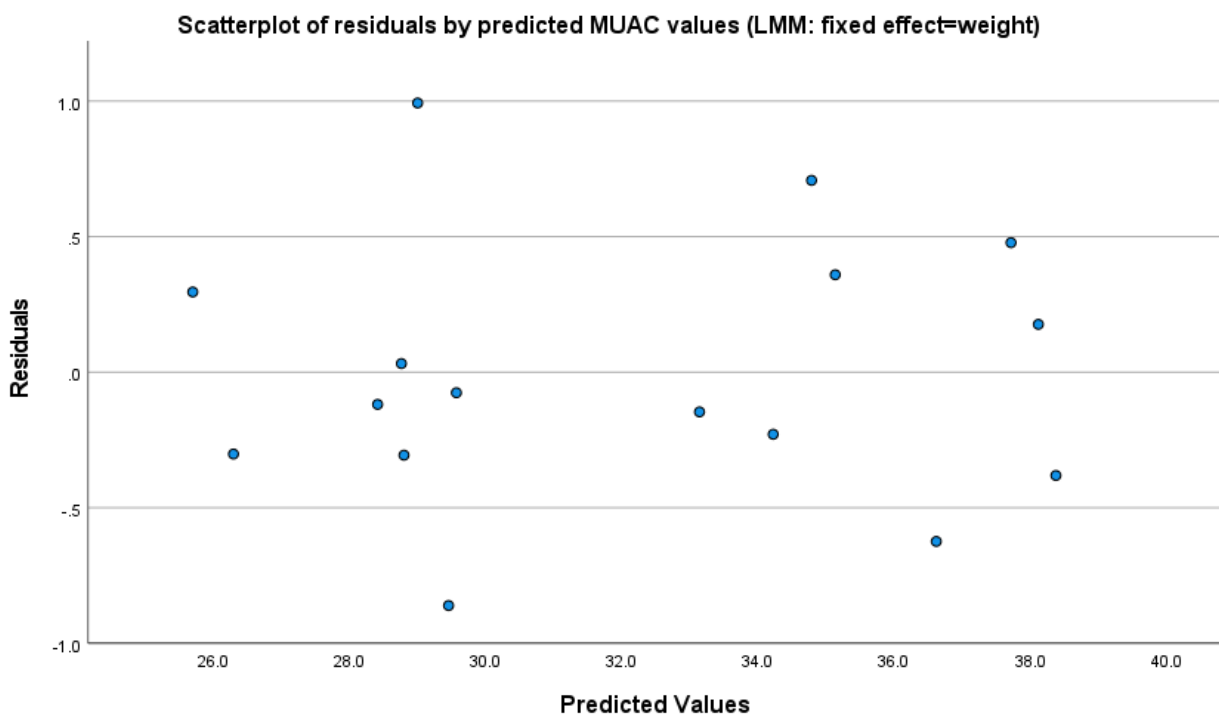
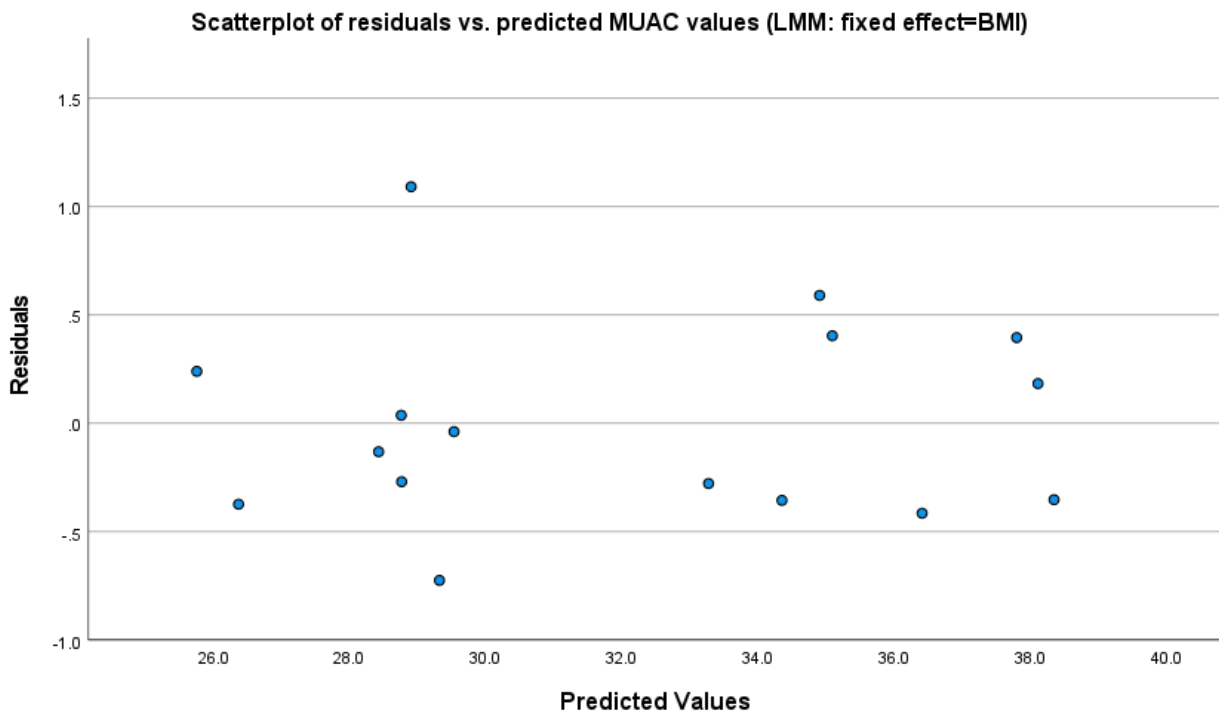
Appendix 8c: Q-Q plots of residuals from the linear mixed models

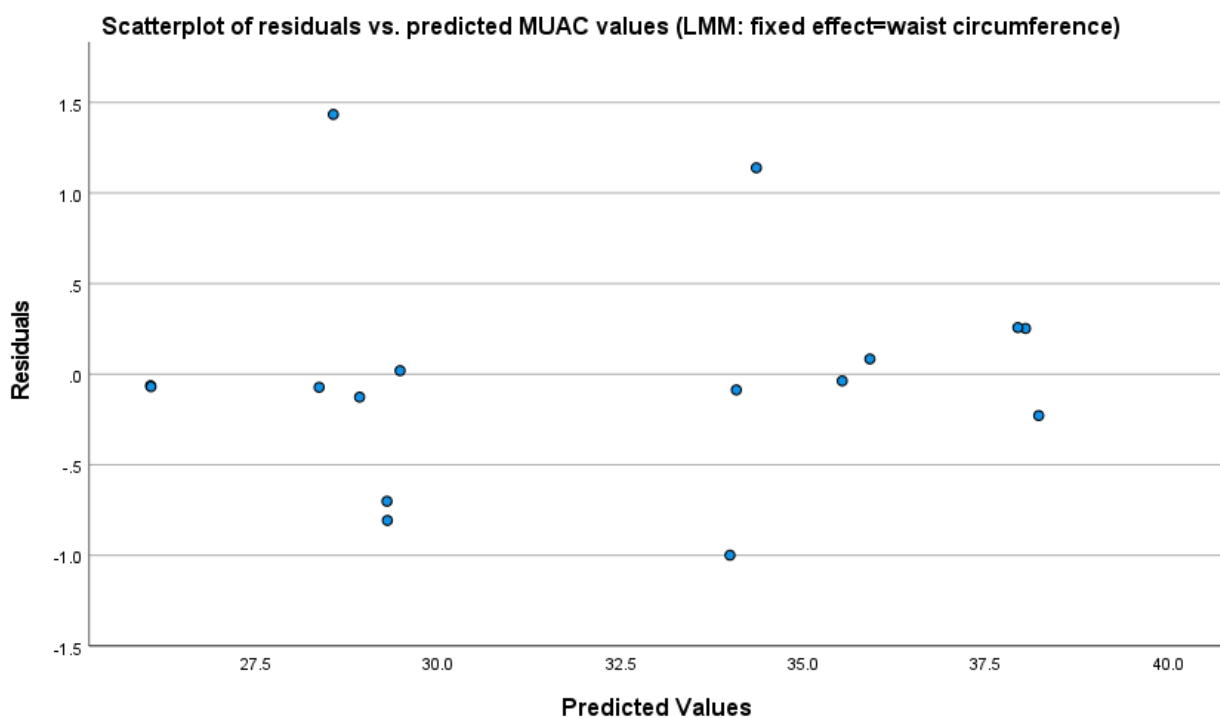
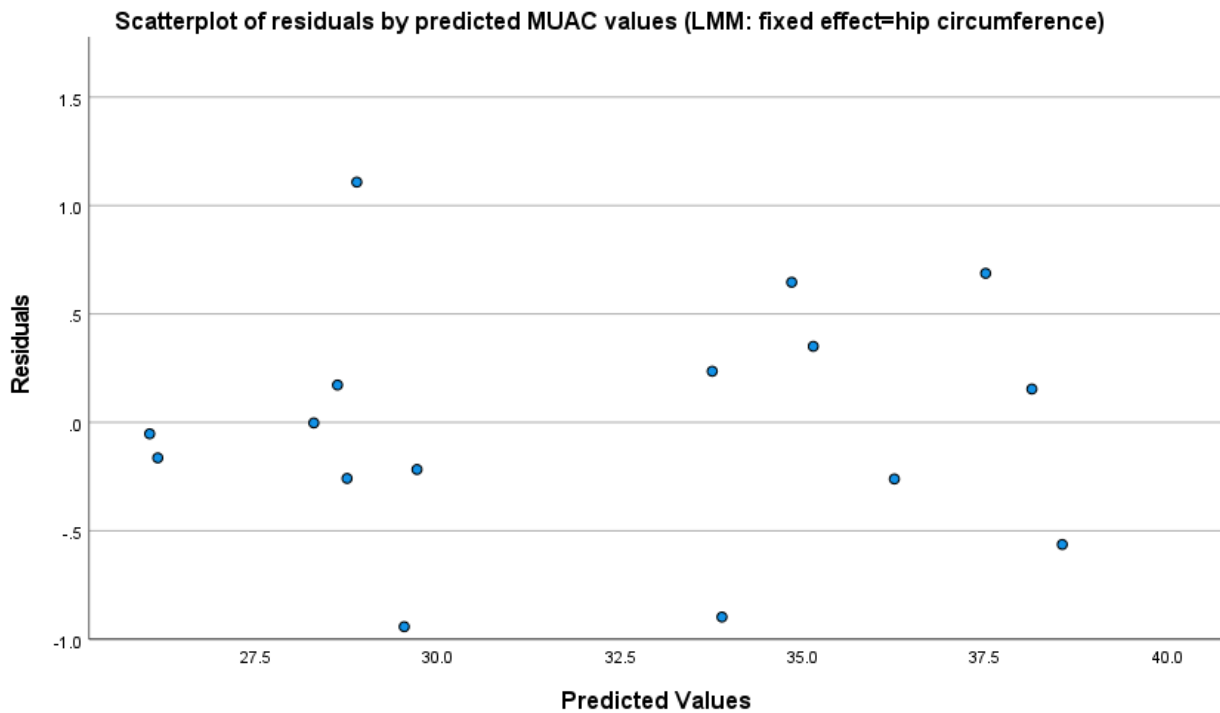




Q-Q plots of the residuals versus the predicted values for the linear mixed models with MUAC as the dependent variable and BMI, weight, hip, and waist circumference as fixed effects. Normal distribution is assumed if the observed values align closely with the straight line representing the expected normal values. Abbreviations: LMM, linear mixed model; MUAC, mid-upper arm circumference; BMI, body mass index.

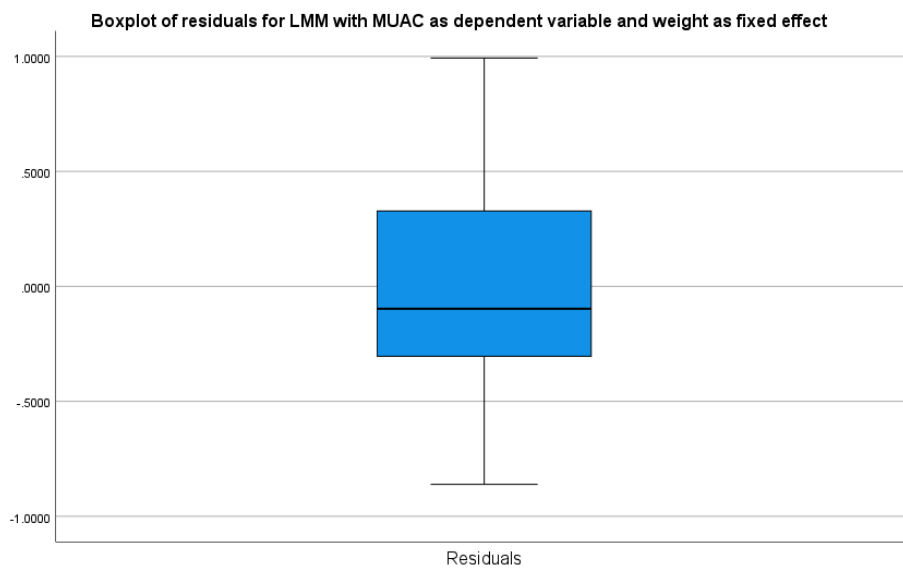
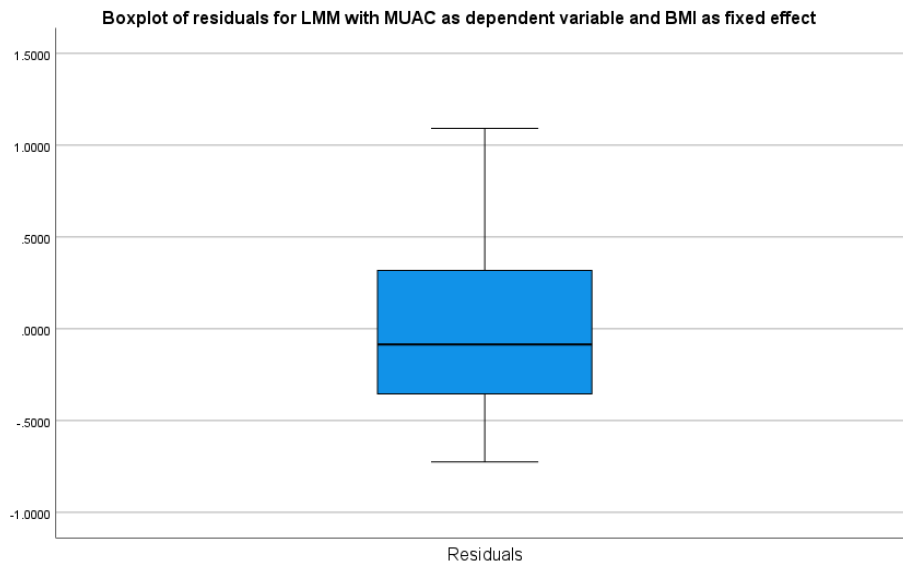
Appendix 8d: Scatterplots of residuals versus predicted values from the linear mixed models

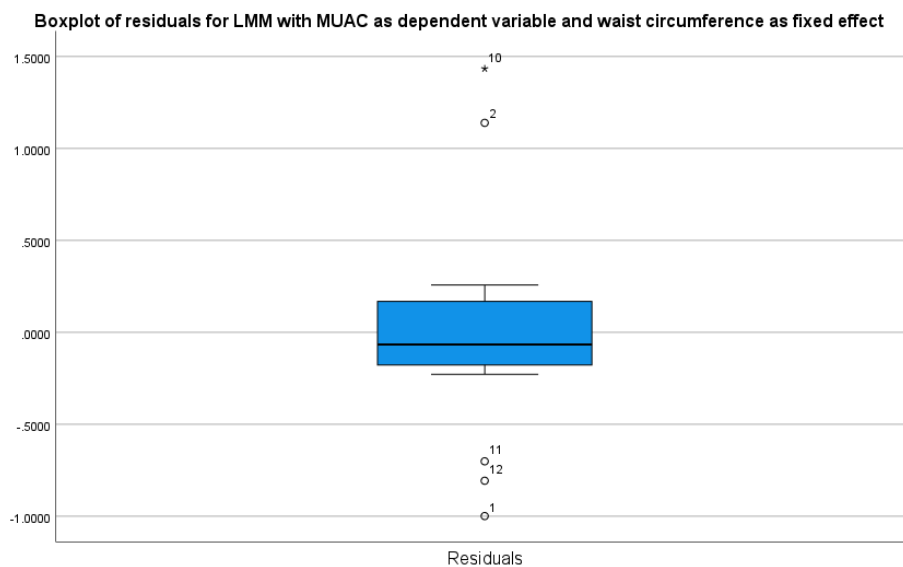
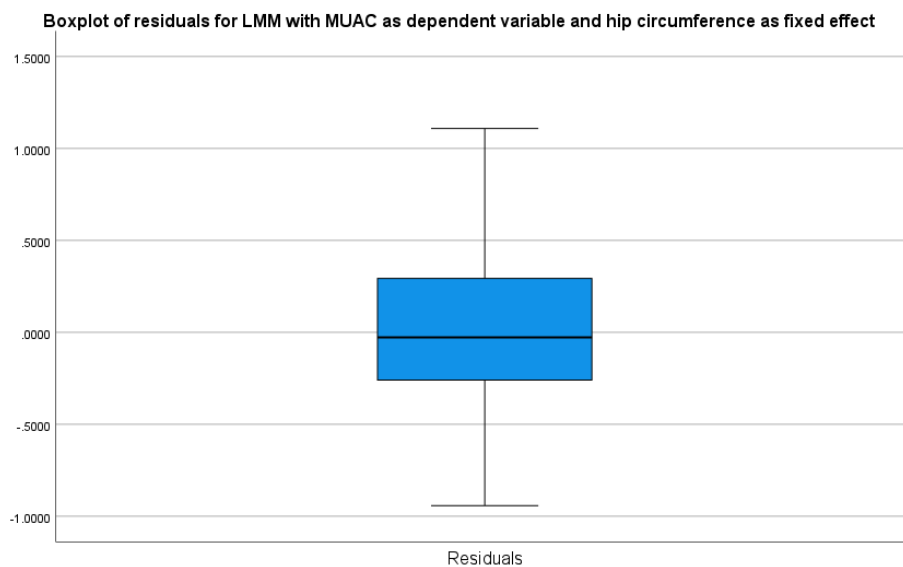




Scatterplots of the residuals versus the predicted values for the linear mixed models with MUAC as the dependent variable and BMI, weight, hip, and waist circumference as fixed effects. A random, horizontal distribution of the points around zero indicates that the assumption of homoscedasticity is met. Abbreviations: MUAC, mid-upper arm circumference; LMM, linear mixed models; BMI, body mass index.

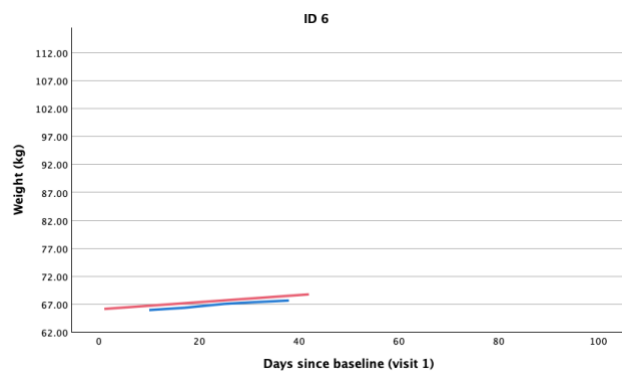
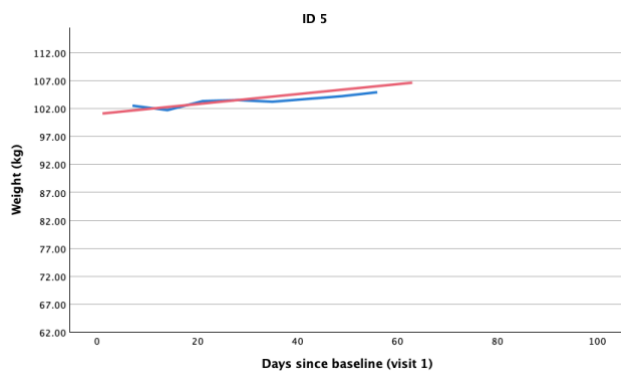
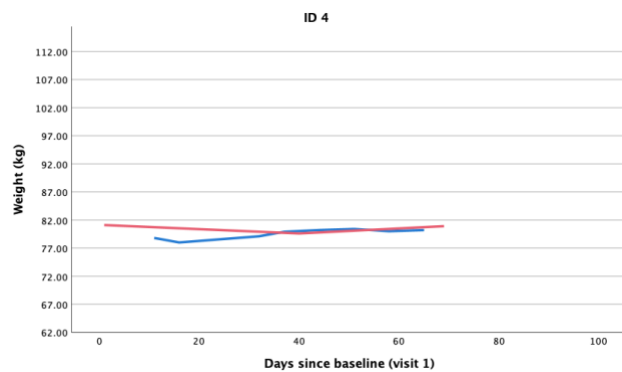
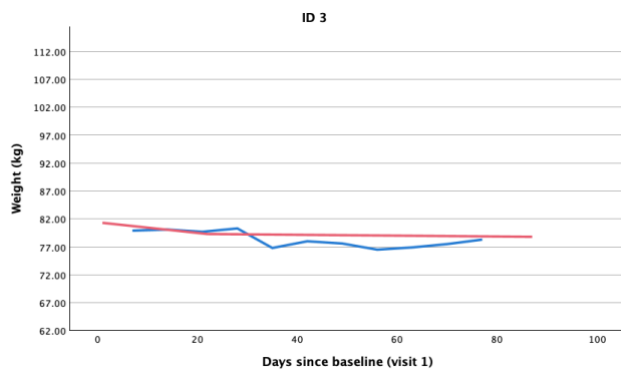
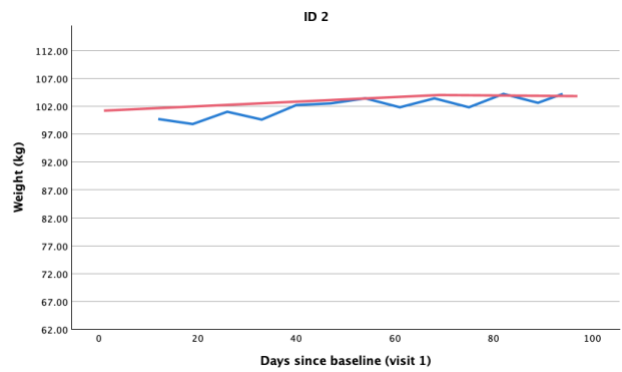
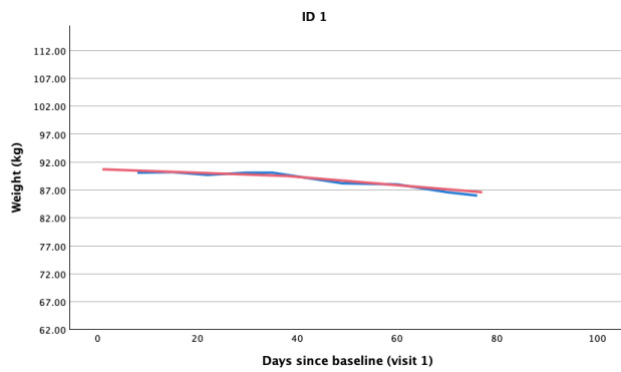
Appendix 8e: Boxplots of residuals for LMMs





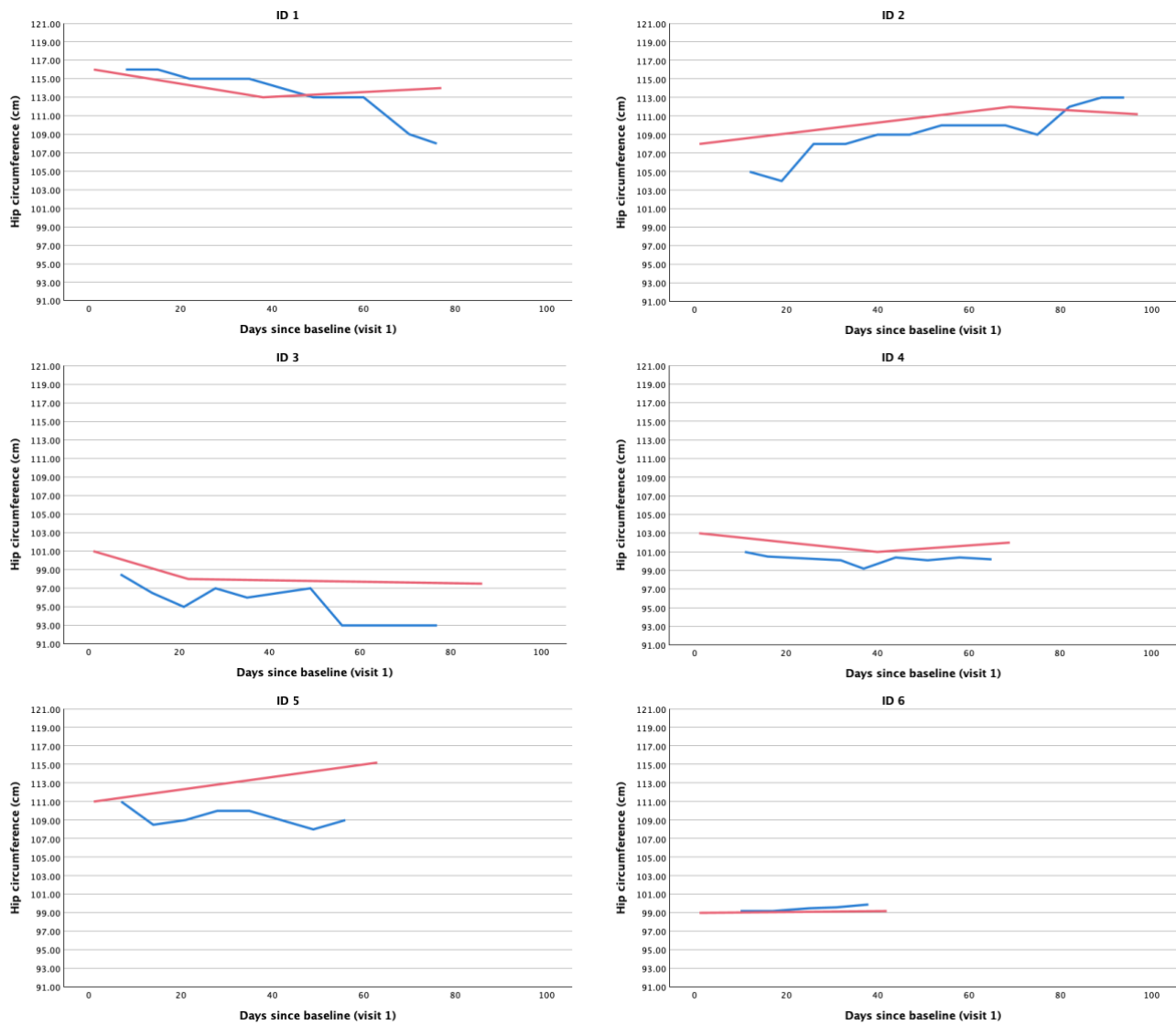
Boxplots of residuals for the linear mixed models with MUAC as the dependent variable and BMI, weight, hip, and waist circumference as fixed effects. Each boxplot displays the median, interquartile range and potential outliers. Abbreviations: LMM, linear mixed model; MUAC, mid-upper arm circumference; BMI, body mass index.

Appendix 9a: Home measurements (weight)



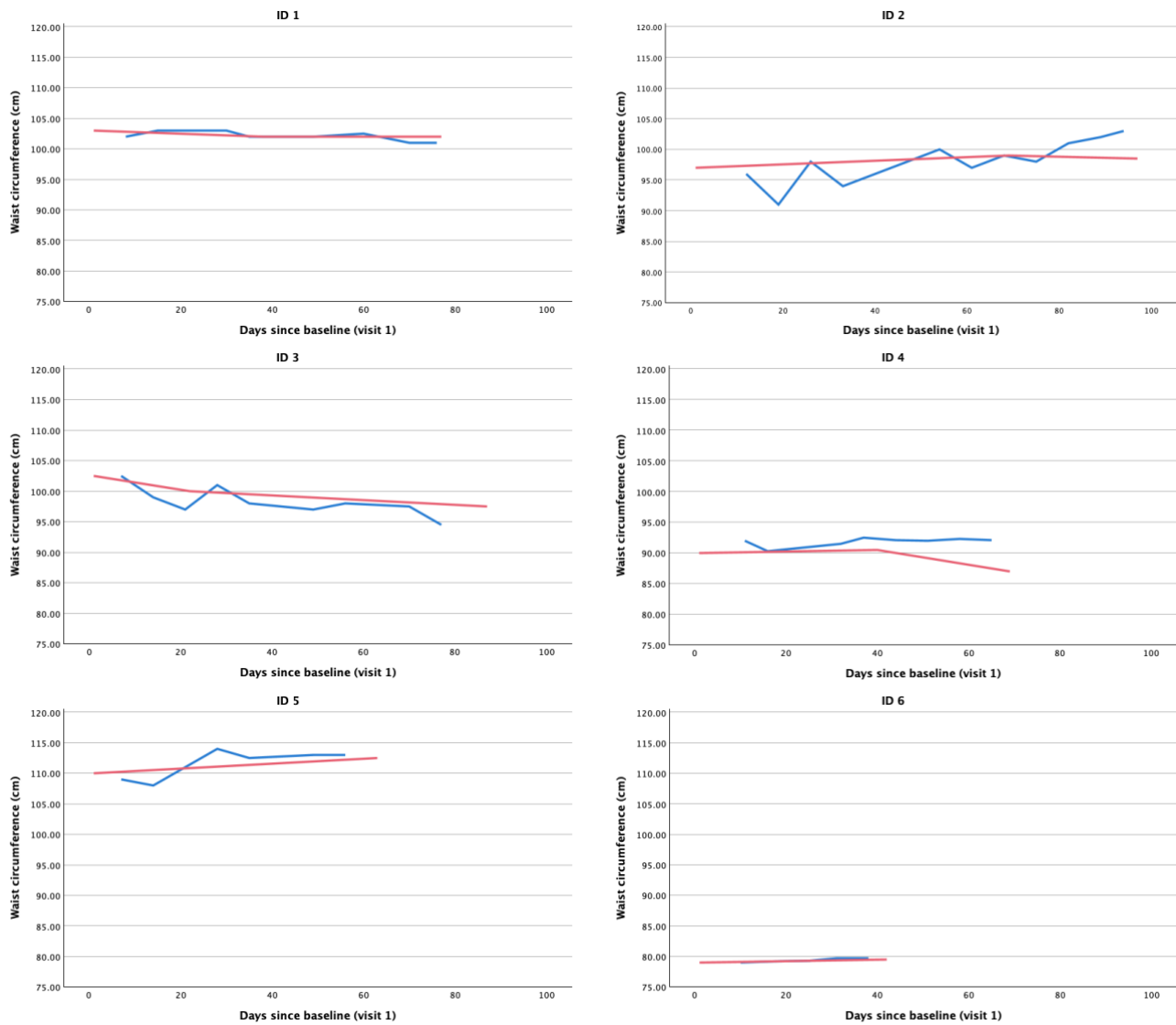
Weight trajectories (hospital vs. home). Individual trajectories (ID 1-6) of weight are shown; hospital visits in pink and home measurements in blue. Time is expressed in days since baseline (hospital visit 1).

Appendix 9b: Home measurements (hip circumference)



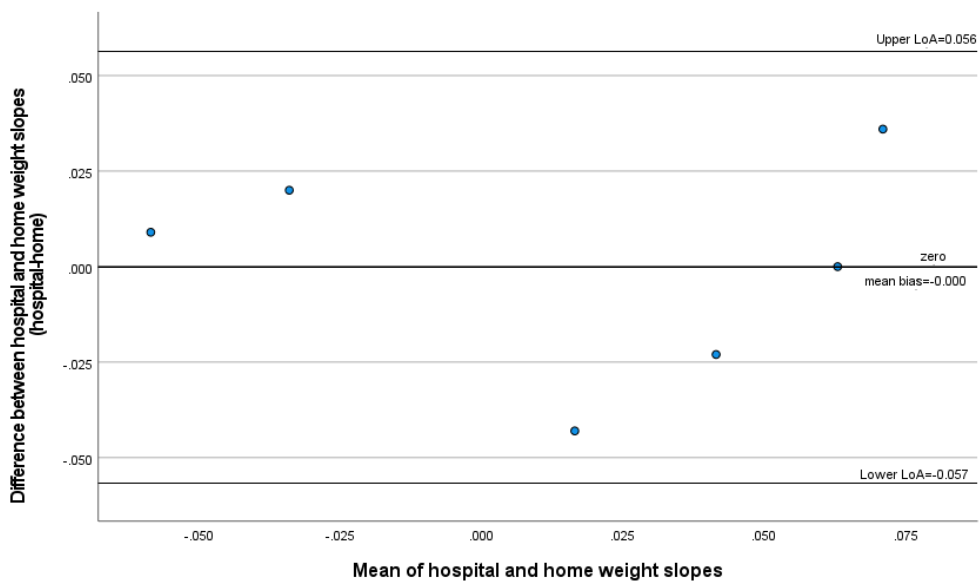
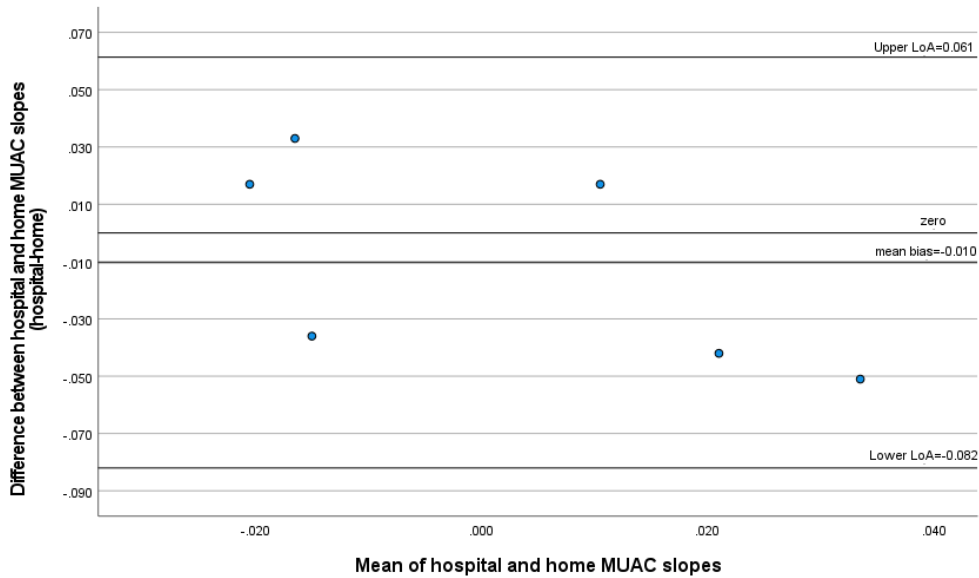
Hip circumference trajectories (hospital vs. home). Individual trajectories (ID 1-6) of hip circumference are shown; hospital visits in pink and home measurements in blue. Time is expressed in days since baseline (hospital visit 1).

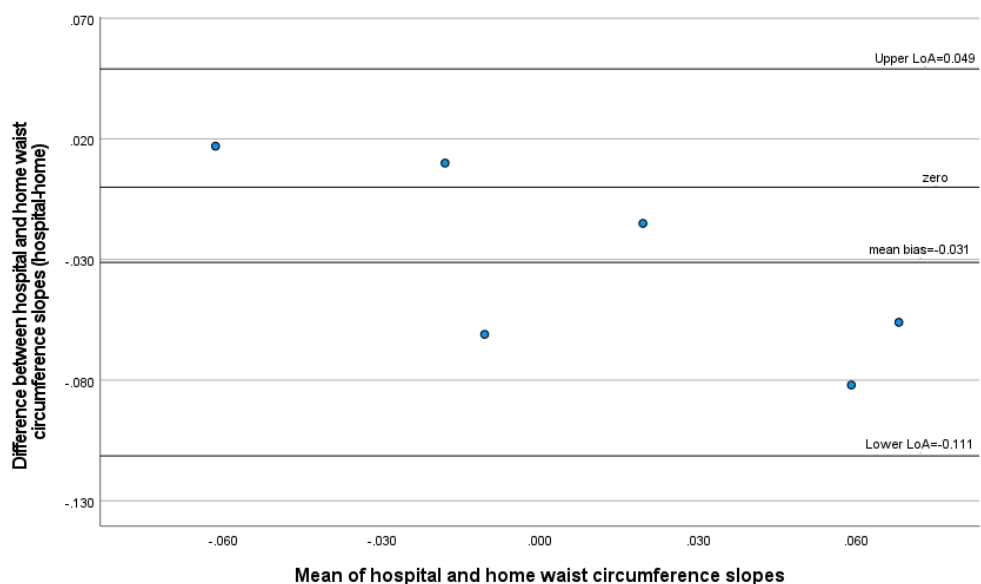
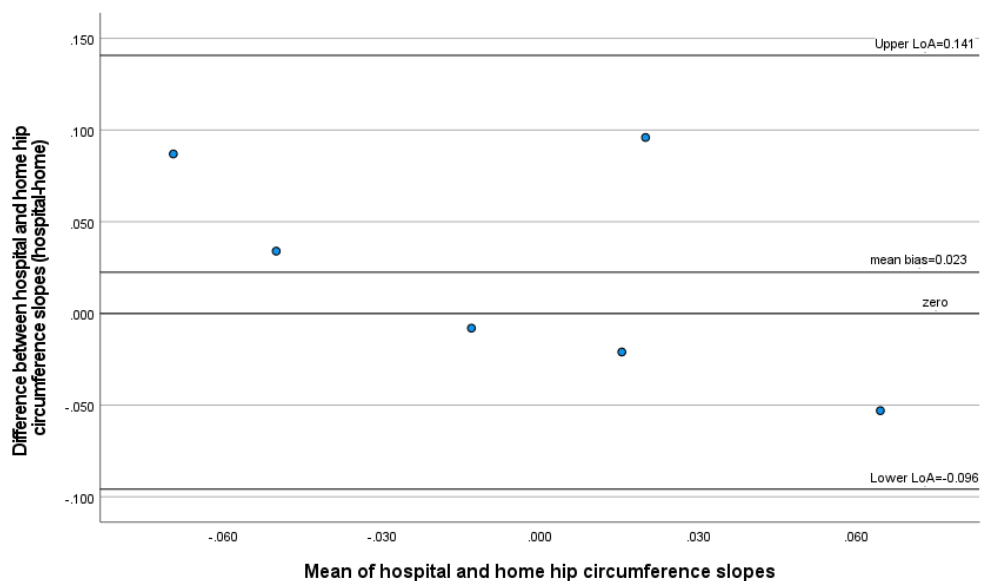
Appendix 9c: Home measurements (waist circumference)



Waist circumference trajectories (hospital vs. home). Individual trajectories (ID 1-6) of waist circumference are shown; hospital visits in pink and home measurements in blue. Time is expressed in days since baseline (hospital visit 1).

Appendix 10: Bland-Altman plots to assess agreement between hospital and home measurement slopes

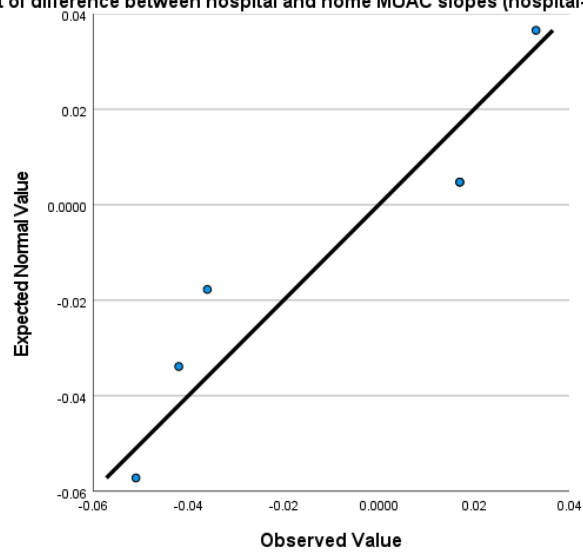




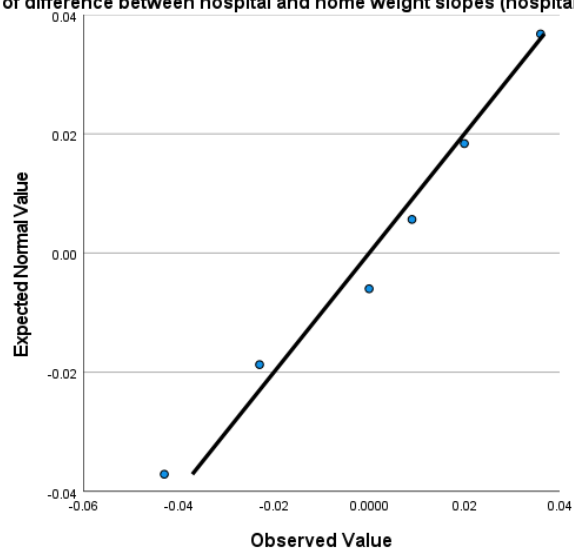
Each plot displays the difference between the slopes (hospital – home) on the y-axis against their mean, displayed on the x-axis. Horizontal reference lines were added, representing mean bias and the 95% LoA. Abbreviations: MUAC, mid-upper arm circumference; LoA, limits of agreement.

Appendix 11: Q-Q plots of the differences between hospital and home measurement slopes

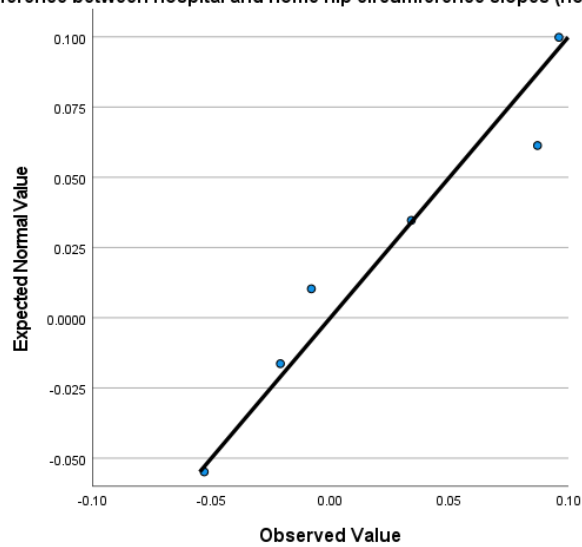
Q-Q Plot of difference between hospital and home MUAC slopes (hospital-home)



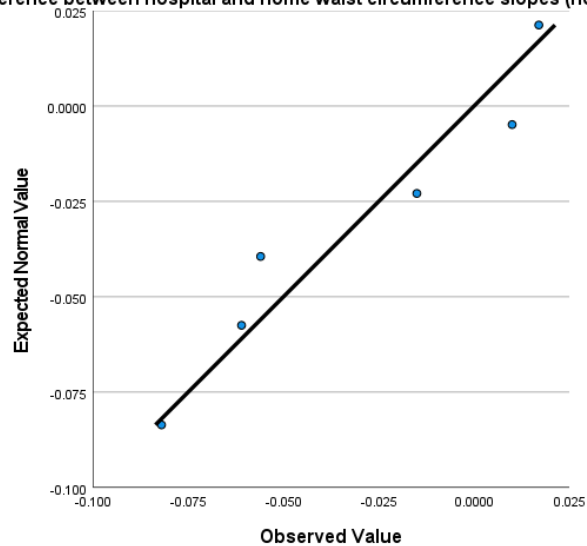
Q-Q Plot of difference between hospital and home weight slopes (hospital-home)



Q-Q Plot of difference between hospital and home hip circumference slopes (hospital-home)



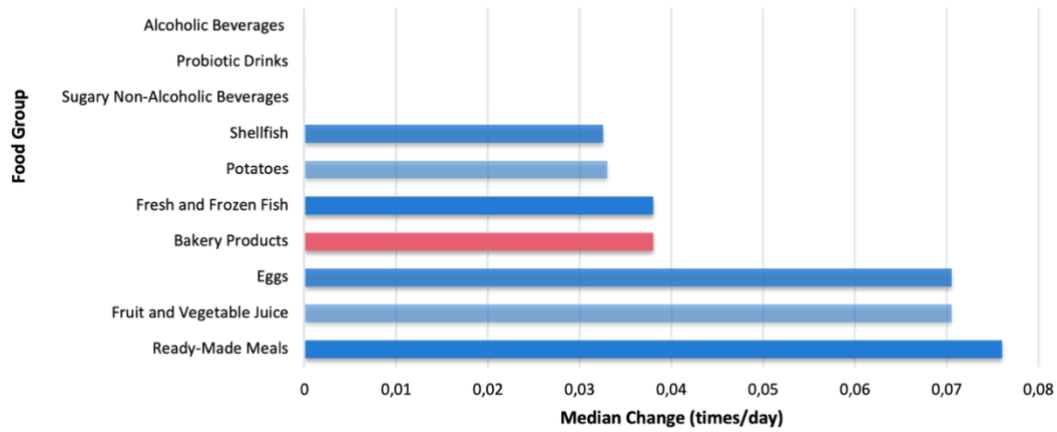
Q-Q Plot of difference between hospital and home waist circumference slopes (hospital-home)



Q-Q plots used to check the assumption of normality of the difference between the hospital and home measurement slopes for MUAC, weight, hip, and waist circumference. Normal distribution is assumed if the observed values align closely with the straight line representing the expected normal values. Abbreviations: MUAC, mid-upper arm circumference.

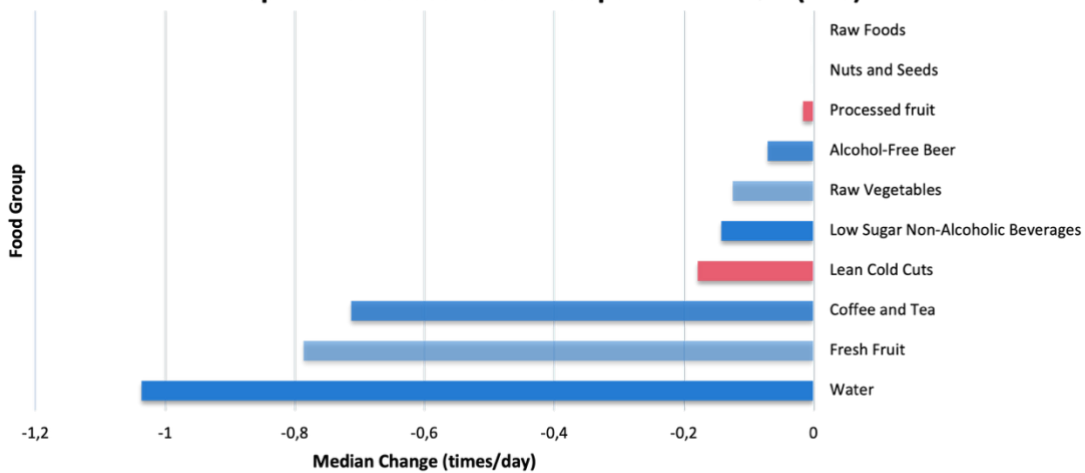
Appendix 12: Supplementary top 10 food group intake changes by visit

Top 10 Increased Food Groups: Δ Visit 1 $\rightarrow$ 2 (n=6)

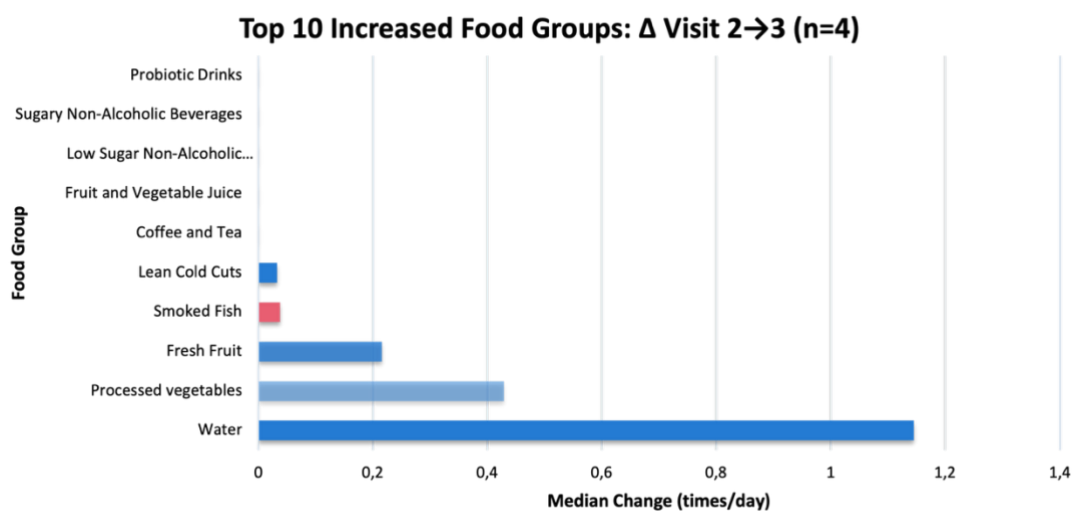


A

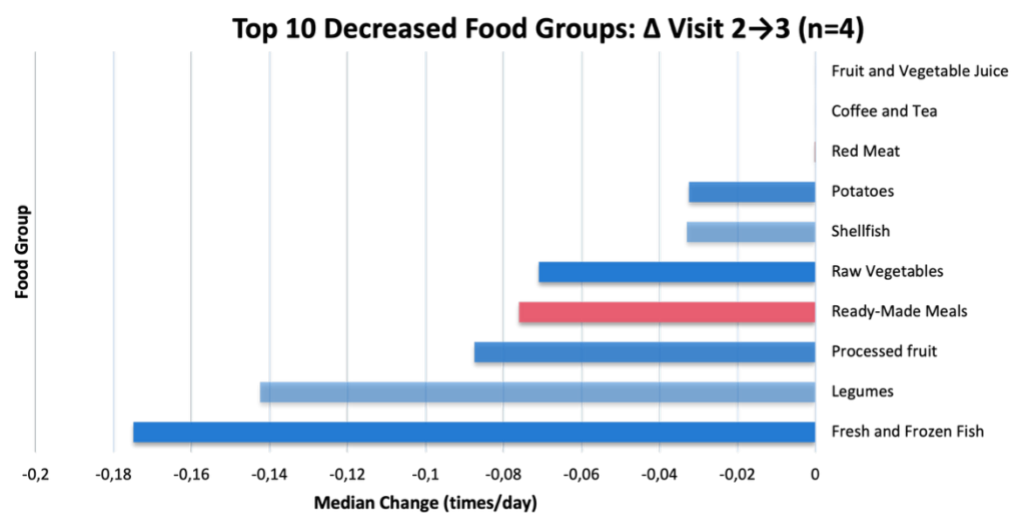
Top 10 Decreased Food Groups: Δ Visit 1 $\rightarrow$ 2 (n=6)



B



C



D

Change in the top 10 food groups showing the greatest median change in intake frequency (times/day) between consecutive visits. Panels A (increase) and B (decrease) show changes from Visit 1 to 2 (n=6), while C (increase) and D (decrease) show changes from Visit 2 to 3 (n=4).

