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Adipose-derived stem/progenitor cells from lipoaspirates: A comparison between the Lipivage200-5 liposuction system and the Body-Jet liposuction system

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Adipose-derived stem/progenitor cells;
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Body-Jet;
Stem cell characterization

Summary *Background:* Adipose-derived stem/progenitor cells (ADSPCs) are under investigation in many clinical applications for their regenerative potential in a variety of autoimmune, degenerative, and inflammatory diseases. Adipose tissue, which is mainly harvested by manual liposuction, is the main source of these ADSPCs.
Objective: In the past years, a variety of different liposuction devices have been commercialized. To ensure a high quality of obtained ADSPCs, it is crucial to show the advantages and disadvantages of frequently used liposuction methods.
For this reason, the objective of this study was to compare ADSPCs harvested by either the suction-assisted LipiVage200-5 or the water-assisted Body-Jet system.
Methods: The proliferation potential of ADSPCs, harvested from 20 patients, was assessed by cumulative population doublings (cumPD), population doubling time (PDT), colony-forming units (CFU), and cell metabolism assays. To prove the multipotency of the primary isolated cells, ADSPCs were induced to differentiate into adipogenic, osteogenic, and chondrogenic lineages.

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Results: Our data show a significantly higher cumPD, as well as a significantly lower PDT for cells obtained by the Body-Jet system. No significant differences were found regarding the CFU efficiency and the cell metabolism. Furthermore, we showed that the adipogenic, osteogenic, and chondrogenic potential of ADSPCs is similar in both groups.
Discussion/conclusion: In our study, we provide evidence that the cell characteristics and the functional properties of ADSPCs isolated after liposuction with different techniques are largely similar. However, we observed a significantly higher cumPD and a slightly higher adipogenic potential in cells isolated after liposuction with the Body-Jet system. Different cannula sizes and sheer stresses in the used methods might play a role here.

Introduction

Adipose tissue can be used in a wide range of clinical applications, including autologous fat grafting and lipofilling. Liposuction has become an important method to obtain fat tissue for further therapeutic purposes. Adipose tissue is a complex and highly active metabolic and endocrine organ composed of adipocytes, loose connective tissue matrix, and the stromal vascular fraction (SVF). The SVF consists of preadipocytes, capillary endothelial cells, infiltrated monocytes/macrophages, and a population of multipotent adipose-derived stem/progenitor cells (ADSPCs)[1,2]. It can be isolated by enzymatic digestion of adipose tissue, and some clinicians already use the SVF, for example, in cell-enriched lipotransfers[3]. Zuk et al. have previously described a stem/progenitor cell population in human adipose tissue that displays self-renewal potential and multilineage potency[4]. Thus, ADSPCs fulfill all characteristics of multilineage stem/progenitor cells, including differentiation and proliferation capacity, as well as clonogenicity[5]. For clinical purposes, ADSPCs seem to be the most promising cells of the SVF for the purpose of regenerative medicine. Since the discovery of these cells, the number of fields for their application in tissue engineering and regenerative medicine has grown immensely. Because of their mesodermal origin, the clinical utilization of these cells seems obvious in the field of bone, cartilage, and tendon repair[6-10]. Other areas of interest range from cardiovascular tissue regeneration and nerve repair to immunomodulatory effects of ADSPCs[11-15]. Furthermore, ADSPCs display several advantages, when compared to bone marrow-derived stem cells (MSCs). In contrast to MSCs, ADSPCs can be more easily and more safely obtained through liposuction. The latter procedure is also associated with a higher harvest[16].

Currently, several methods are available for harvesting adipose tissue. They range from classical resection, conventional suction-assisted liposuction to newer techniques such as the water-jet-assisted, nutational infrasonic, and ultrasound-assisted liposuction[17,18]. These methods are developing continuously, and newer methods will be introduced in the future. Specifically, the Body-Jet and LipiVage200-5 liposuction devices are reported to provide favorable clinical outcomes. These two frequently used methods show great differences with regard to the fat-harvesting procedure. The suction-assisted LipiVage200-5 system is a single-use, disposable system that allows to obtain 200 ml of lipoaspirate. This technique provides efficient handling, as fat harvesting and subsequent washing steps are carried out in one step. The harvested tissue can be re-injected in the same treatment. After removing fluid and oil by means of filtration, it is used primarily for lipofilling in the field of esthetic surgery, as well as in plastic and reconstructive surgery[19,20]. In contrast, the Body-Jet system is a water-jet-assisted liposuction method. Hence, the liposuction tube, which is connected to a negative-pressure pump and a water pump, enables the ejection of fan-shaped water in specified frequencies during liposuction[21]. This technique is known to reduce cardiovascular side effects, as the fluid injected into the patient is much lower than that during other liposuction methods[22].

To maintain a high clinical standard, it is essential to analyze and compare the most frequently used liposuction techniques. To date, there are several studies that compare either the LipiVage or the Body-Jet system to classic manual methods. Ferguson et al. compared the viability of cells isolated from adipose tissue harvested with the LipiVage system and classic manual liposuction[19]. Bony et al. have recently published a study comparing cell properties of ADSPCs isolated after manual and water-jet-assisted liposuction[22]. Furthermore, studies have compared novel liposuction techniques that have not yet found widespread application. Recently, Bajek et al. evaluated biological properties of ADSPCs isolated after liposuction with the newer laser-assisted technique, as well as after power-assisted liposuction and surgical resection[23]. To the best of our knowledge, there is no study specifically investigating the two general most widespread liposuction approaches. For this reason, we compared the influence of LipiVage and Body-Jet liposuction methods for ADSCPs properties by examining their clonogenic potential, proliferation capacity, metabolic activity, and differentiation potential into the adipogenic, osteogenic, and chondrogenic lineages.

Methods

Ethics statement and sample acquisition

Human lipoaspirates were obtained from 20 patients undergoing liposuction after written informed consent was signed by them. Patients received liposuction either as an esthetical procedure or for the treatment of carpometacarpal joint osteoarthritis using unprocessed autologous fat tissue for injection into the joint capsule. The study was approved by the Ethics Committee of Ludwig-Maximilians-

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Table 1 Patient information.

Patient overview	Female donors total	Male donors total
Number	10	10
Average age	51.2 years (range 27-69 years)	46.5 years (range 20-69 years)
Harvesting site	Abdomen and thighs	Abdomen and breast
Average fat sample weight	8.7 g (range 4.6-10 g)	9.3 g (range 6.2-10.2 g)

University, Munich (275-16). Patient information is listed in Table 1.

All lipoaspirates were harvested either through water-jet-assisted liposuction with the Body-Jet system (Human Med AG, Germany) or through suction-assisted liposuction performed with the LipiVage system (Bondimed, Austria) by a surgeon according to common surgical standards. The Body-Jet liposuction technique was used for patients receiving esthetic liposuction, whereas the LipiVage technique was used for obtaining adipose tissue for injection of lipoaspirate into the carpometacarpal joint capsule. Tumescent fluid containing saline, lidocaine, and epinephrine was used for liposuction with the Body-Jet system but not for liposuction with the LipiVage technique. To obtain comparable samples of adipose tissue, samples (300 g) harvested with the Body-Jet device were centrifuged for 5 minutes and the mid-layer, consisting of tumescent fluid, was extracted before further use of the samples for experiments.

All patients were tested negative for HIV (human immunodeficiency virus), HCV (hepatitis C virus), and HBV (hepatitis B virus). The average patient age was 50.15 years. All patients were in a generally healthy condition.

Cell isolation and culture condition

ADSPCs were enzymatically isolated from approximately 10 g lipoaspirate with a semi-automated centrifuge system (ARC™-Processing Unit, InGeneron, USA) following the manufacturer's protocol using their enzyme blend (Matrase™) and 37 °C warm lactated Ringer's solution (Fresenius Kabi, Germany). The obtained SVF was resuspended and cultured in standard culture medium consisting of DMEM-high glucose (Thermo Fisher Scientific, USA) supplemented with 10% fetal bovine serum (FBS, Sigma-Aldrich, USA), 100 U/ml penicillin and 100 μg/ml streptomycin (Life Technologies, USA). During cell expansion and experiments, the medium was changed twice per week. Cells were cultured in a humidified incubator to approximately 80% confluency, detached with 0.5% Trypsin (Merck, Germany), and frozen down in passage 1 for further experiments.

Cell characterization

To examine the clonogenic potential, colony-forming unit (CFU) efficiency (CFU% = (number of colonies/initial cell number)×100) was determined following the protocol described previously[24]. ADSPCs were seeded at the concentration of 10 cells/cm^2 in 10 cm culture dishes, cultured for 10 days, and the formed colonies were visualized by staining using a 0.5% solution of crystal violet in methanol.

Proliferation capacity was quantified by calculating the cumulative population doublings (cumPD) and the population doubling time (PDT) during 30 days, corresponding to 10 consecutive passages, following the protocol described in[25].

Metabolic activity was examined with a WST-1 (water-soluble tetrazolium) assay after a protocol detailed in[24]. Optical density (OD) was measured with an ELISA-reader (MultiSkan FC, Thermo Fisher Scientific, USA) at a wavelength of 450 nm. A 620 nm filter was used as the reference wavelength.

Adipogenic differentiation

Adipogenic differentiation was induced for 21 days according to the protocol described earlier[25]. Briefly, 5000 cells/cm^2 were seeded in 6-well plates and expanded to total confluence. After 5 days, differentiation was initialized by changing normal culture medium to induction medium, consisting of standard medium supplemented with 1 μM dexamethasone, 0.2 mM indomethacin, 0.01 mg/ml insulin, and 1 mM 3-isobutyl-1-methyl-xanthin (all from Sigma-Aldrich) for five days. The induction phase was followed by a two-day conservation phase using standard medium with 4 mM L-glutamine and 0.01 mg/ml insulin (all from Sigma-Aldrich). Cells cultured in standard culture medium served as controls.

Lipid vacuole staining

After 21 days, cells were washed with PBS and fixed with 4% paraformaldehyde (PFA). Subsequently, cells were stained with 5 mM Bodipy 493/503 (Thermo Fisher Scientific, USA) solution. Newly formed lipid droplets were quantified with the open-source program ImageJ by calculating the fraction of the area occupied by the droplets relative to the total area[26].

Osteogenic differentiation

For osteogenic differentiation, a standardized protocol was followed[25]. Briefly, 5000 cells/cm^2 were plated in 6-well plates and expanded to total confluence. Differentiation was initialized by exchanging standard culture medium with induction medium consisting of standard culture medium supplemented with 100 nM dexamethasone, 10 mM β-glycerolphosphate and 50 μM ascorbic acid (all from Sigma-Aldrich). The medium was changed twice a week. Cells in standard medium served as a control.

Alizarin red staining

After 21 days, cells were stained after fixation with a 40 mM Alizarin Red solution (pH 4.1, adjusted with ammonium hydroxide). Afterwards, stained cells were imaged with a Zeiss Axiovert 40 CFL microscope. For quantification, the bound

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dye was dissolved, followed by multiple centrifugation steps and the collection of the supernatant. Finally, samples were measured at a wavelength of 405 nm with an ELISA reader (Thermo Fisher Scientific, USA) and compared to a standard curve.

Chondrogenic differentiation

Chondrogenic differentiation was performed in pellet culture as described before[27]. Briefly, ADSPCs were preconditioned during monolayer expansion in a hypoxia incubator (2% O_2, 5% CO_2, 37 °C) (Sanyo, Japan) for 4 days. For pellet formation, 2.5×10^5 cells were centrifuged at 400 g for 5 minutes in 96-well, v-bottom polypropylene microplates (Corning, USA). Basic chondrogenic medium consisted of DMEM-high glucose (Thermo Fisher Scientific, USA) with 10 μM dexamethasone, 1 mM sodium pyruvate, 0.195 mM ascorbic acid 2-phosphate, 1% ITS+3 (insulin, transferrin, and selenite, all from Sigma-Aldrich), and 1% Penicillin-Streptomycin. This basic chondrogenic medium was used for controls. Additionally, BMP6 (100 ng/ml) and TGFB3 were added to the differentiation medium (20 ng/ml, both R&D systems). Pellets were cultured under hypoxic conditions, and the medium was changed every two days.

Safranin-orange and aggrecan staining

After 28 days, cell pellets were fixed, washed, and incubated overnight in a 30% sucrose solution in PBS. The next day, pellets were embedded with Tissue-Tek O.C.T (Sakura, USA), compound, and frozen at −80 °C. Embedded pellets were cut with a cryotome, and sections were stained with 0.1% safranin-orange (Sigma-Aldrich, USA) in dH_2O to evaluate the glycosaminoglycan content within the pellets. Furthermore, immunocytochemistry on pellet sections for aggrecan was performed. The anti-aggrecan primary antibody (Chemicon AB1031, USA) was diluted 1:600 in a blocking solution consisting of 1% bovine albumin serum (Life Technologies, USA) in PBS and incubated overnight at 4 °C. The following day, sections were washed in PBS and then the secondary antirabbit antibody (Vectastain, USA) was 1:400 diluted and added into blocking solution for 1 h. Afterwards, sections were washed in PBS and stained with 3,3ʻdiaminobenzidine (DAB) (Sigma-Aldrich, USA) for 7 min, followed by another washing step in tap water. Subsequently, pellet sections were mounted with Roti-Mount-Aqua (Roth, Germany). In parallel, negative control stainings were performed by omitting the primary antibody. Finally, pictures were taken on an AxioObserver Z1 microscope using AxioCam ICc3 color camera (Carl Zeiss, Germany). Safranin-Orange- and aggrecan-positive areas were quantified with the open-source program ImageJ and compared to the total pellet area.

Statistical analysis

For all experiments, 10 donors per liposuction method were evaluated. All cell culture experiments were performed in triplicates except for the cumPD and CFU-assay. A Mann-Whitney-*U* test was used for statistical analysis, and a *p*-value of ≤ 0.05 was considered significant. All values were plotted as box and whisker plots (median, quartiles, and minimum/maximum).

Results

Cells isolated with the Body-Jet system show a significantly higher proliferation rate than those isolated with the Lipivage200-5 system

The extent of self-renewal capacity, including the proliferation potential, is one of the main characteristics known to reflect the regenerative potential of ADSPCs. Therefore, we examined the cumPD (Figure 1(A)). During a period of 30 days, ADSPCs isolated with the BodyJet system showed a significantly higher cumPD of 15.92 ± 1.86 than the ADSPCs that were isolated with the LipiVage system (cumPD 13.44 ± 1.90). The mean population doubling time (PDT) was 47.12 ± 6.50 h for the Body-Jet and 56.76 ± 8.31 h for the LipiVage system (Figure 1(B)). By monitoring the cell morphology by phase-contrast microscopy during *in vitro* cultivation, we could prove a spindle-like shape typical for mesenchymal fibroblasts during the first weeks of culture (Figure 1(C)). However, most ADSPCs isolated with both methods adopted a flattened shape after 30 days in culture (Figure 1(C)).

To determine the clonogenic potential of the isolated cells, we performed a CFU assay. In both groups, ADSPCs were able to form colonies after a period of 10 days (Figure 2(A/B)). CFU efficiency was comparable between LipiVage (18.53 ± 6.48%) and Body-Jet isolated ADSPCs (18.23 ± 8.29%) (Figure 2(C)).

Furthermore, metabolic activity, measured by a WST-1 assay, resulted in a non-significant difference in mean OD of 0.21 ± 0.16 and 0.19 ± 0.15 in the LipiVage and Body-Jet group, respectively (Figure 3).

ADSPCs isolated from both liposuction methods showed a comparable adipogenic, osteogenic, and chondrogenic potential

To validate stem cell properties, the isolated cells were induced to differentiate toward the adipogenic, osteogenic, and chondrogenic lineages. Cells obtained by LipiVage (Figure 4(A/A')) and water-jet liposuction (Figure 4(B/B')) showed prominent formation of lipid vacuoles after 21 days when stimulated with adipogenic supplements. The control groups from both liposuction methods showed no formation of lipid vacuoles (Figure 4(A/A') and (B/B'), inserts). Quantification of the amount of accumulated intracellular lipid vacuoles revealed a slight but insignificant (p=0.1377) tendency toward a stronger adipogenic differentiation potential in the Body-Jet group (12.45 ± 7.47%) than in the LipiVage system (8.17 ± 4.47%; Figure 4(C)).

ADSPCs derived from both methods showed strong mineral depositions (Figure 5(A/B)), which were absent in control cells (Figure 5(A/B), inserts). Quantification of the mineral nodule formation by Alizarin Red staining revealed a minor tendency toward a stronger osteogenic potential of

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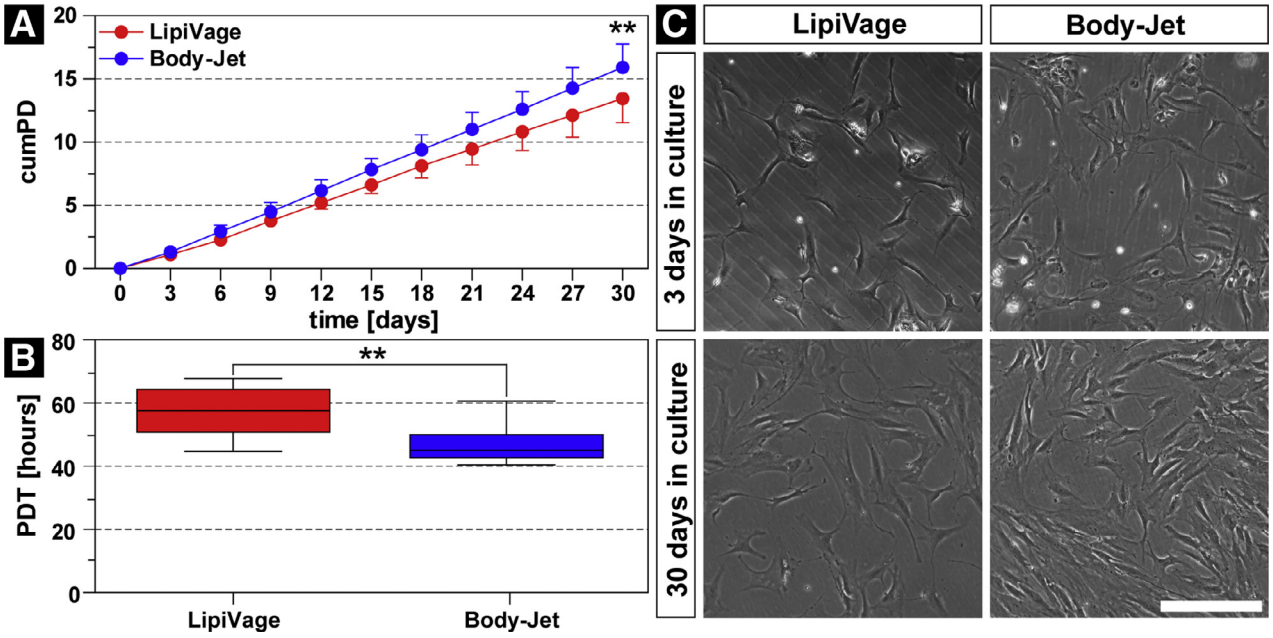

Figure 1 ADSPCs isolated with the Body-Jet system showed a significantly higher cumulative population doubling. Statistical analyses of the mean cumPD (A) after 30 days (corresponding to 10 consecutive passages) revealed a significantly higher rate for cells isolated with the Body-Jet system. The PDT showed a significantly lower rate for cells isolated with the Body-Jet system (B). Phase-contrast microscopy of cells cultivated for 3 days shows a spindle-like cell shape (C). Along with passaging, cells became flattened, resembling the shape of senescence cells (C). Scale bar: 100 μm.

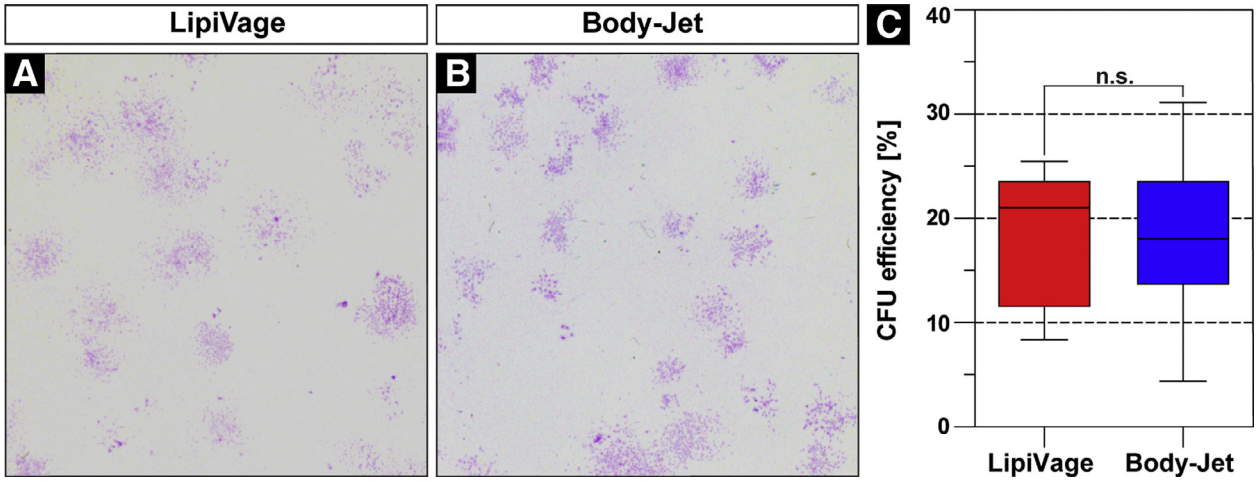

Figure 2 Number of colony forming units did not reveal a significant difference. Formed colonies were visualized with crystal violet after 10 days (A/B). Both groups showed a comparable number of colonies formed, no significant (n.s.) difference could be found (C).

cells derived from Body-Jet samples (1.83 ± 0.96 mM) in contrast to ADSPCs in the LipiVage group (1.65 ± 1.42 mM; Figure 5(C)).

ADSPCs isolated with both liposuction methods were able to differentiate into proteoglycan-producing chondrocytes in pellet culture potential (Figure 6(A/A') and (B/B')), whereas cells from both control groups did not (Figure 6(A/B)). The quantification of the Safranin-Orange-positive area on cryosections of the pellets did not show any significant difference ($p = 0.7394$) in the chondrogenic differentiation potential between cells obtained with the LipiVage (45.06 ± 11.96%) and the Body-Jet (43.75 ± 10.18%; Figure 6(C)). In addition, the quantification of the aggrecan-positive area by immunohistochemical staining did not indicate any significant difference in the chondrogenic differentiation potential between the LipiVage (46.26 ± 9.71%) and Body-Jet (49.70 ± 4.19%; p=0.4318; Figure 6(D)).

Taken together, ADPSCs isolated with the two systems have a high proliferation capacity and can differentiate into the adipogenic, osteogenic, and chondrogenic lineages. However, cells derived from the Body-Jet system proliferate significantly faster and exhibit a slight tendency to

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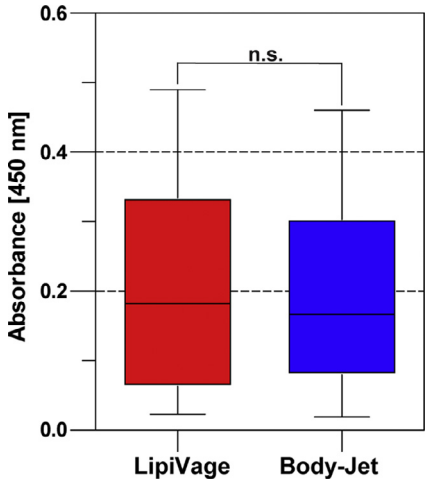

Figure 3 Metabolic activity of isolated ADSPCs is comparable between the LipiVage and Body-Jet isolation methods. The WST-1 measurement was performed with ADSPCs isolated by the two liposuction techniques. There was no significant difference among the different liposuction techniques.

accumulate more lipid vacuoles than ADSPCs isolated with the LipiVage system.

Discussion

In recent years, the regenerative potential of ADSPCs has become an interesting area in the field of regenerative medicine and tissue engineering. Because of legal restrictions, the clinical application of ADSPCs is still in its infancy. However, legal restrictions alone do not constitute the only barrier to a more widespread clinical use of ADSCPs. The incomplete understanding of the effects of different harvesting methods on the properties of these cells presents an additional limitation. Numerous fat-harvesting methods have been compared with regard to their clinical properties such as operative time, harvesting volume, blood loss, skin reactions, and usage costs[28]. However, there is a serious gap regarding the comparison of different liposuction techniques in terms of the preservation of cellular properties. The key question is whether the cellular functions of ADSPCS, derived from adipose tissue harvested with different liposuction techniques, are comparable or differ significantly.

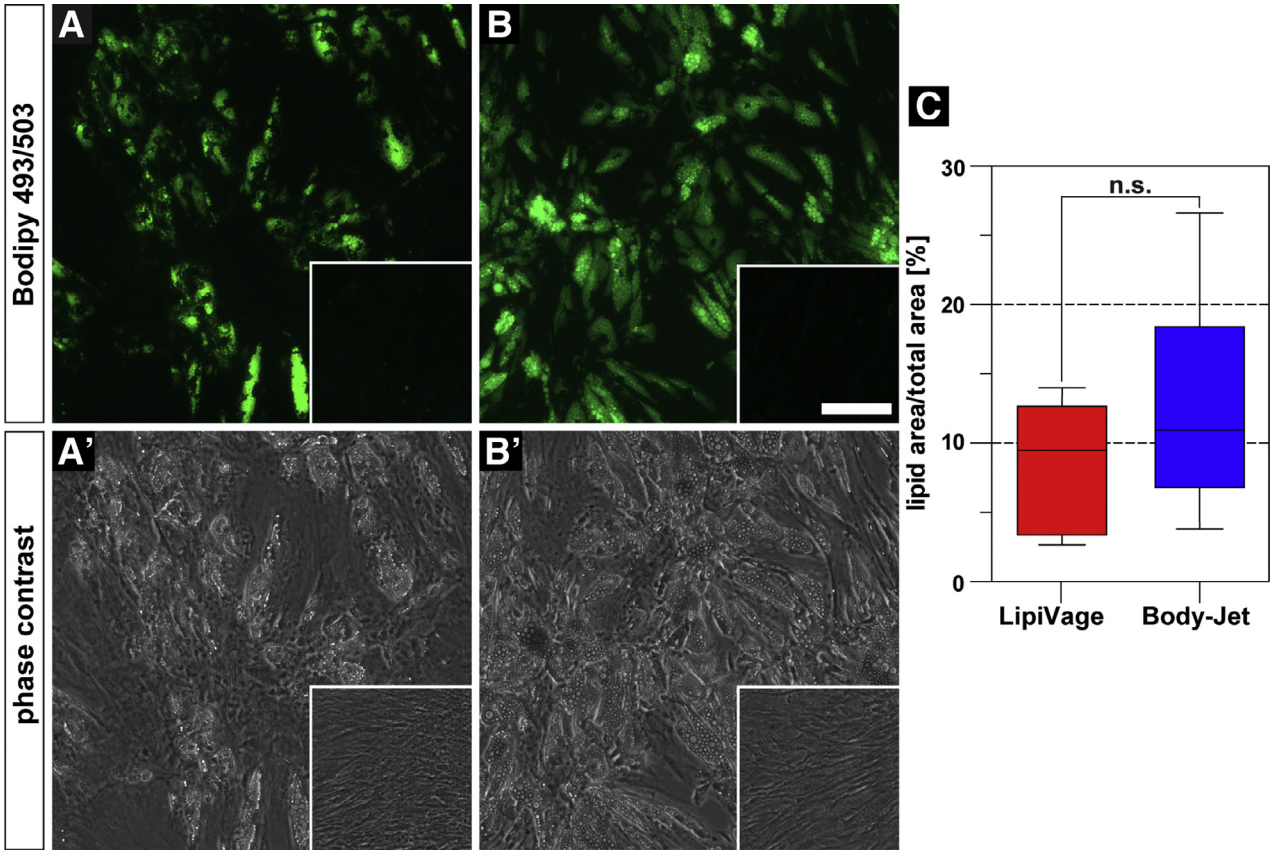

Figure 4 ADSPCs isolated after liposuction with the Body-Jet system exhibit a tendency of stronger adipogenic potential. Accumulated lipid vacuoles (green) were detected by Bodipy staining after 21 days of stimulation with adipogenic supplements (A/B). The phase-contrast microscopy pictures show the same donors at day 21 after adipogenic stimulation (A´/B´). Unstimulated negative controls showed no formation of lipid vacuoles (Fig.4A/A' and B/B', inserts). Quantitative analysis of the accumulated intracellular lipid vacuoles revealed a stronger, but statistically not significant adipogenic differentiation potential in the Body-Jet group compared with the LipiVage (C). Scale bar: 50 μm.

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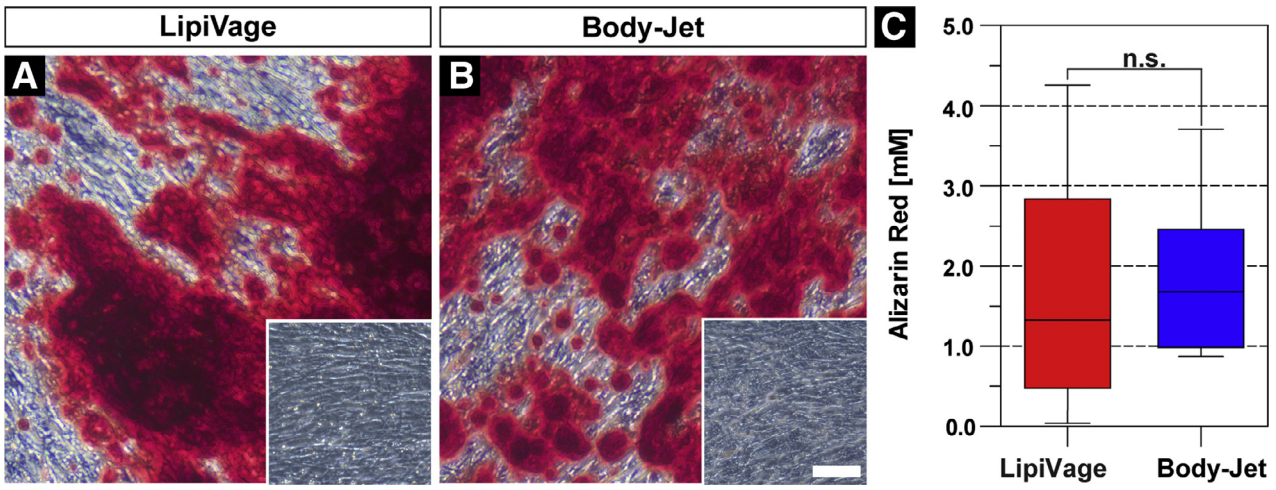

Figure 5 Quantification of extracellular mineralization demonstrates comparable osteogenic differentiation of ADSPCs isolated by LipiVage and Body-Jet. Deposited calcified matrix was revealed by Alizarin Red staining after 21 days (A/B). Unstimulated negative controls showed no formation of extracellular mineralization (A/B, inserts). Quantitative analysis of the Alizarin Red accumulation (stained red) revealed a moderate tendency towards a stronger osteogenic differentiation potential in the Body-Jet group when compared to the LipiVage group (C). However, the difference is not significant. Scale bar: 400 μm.

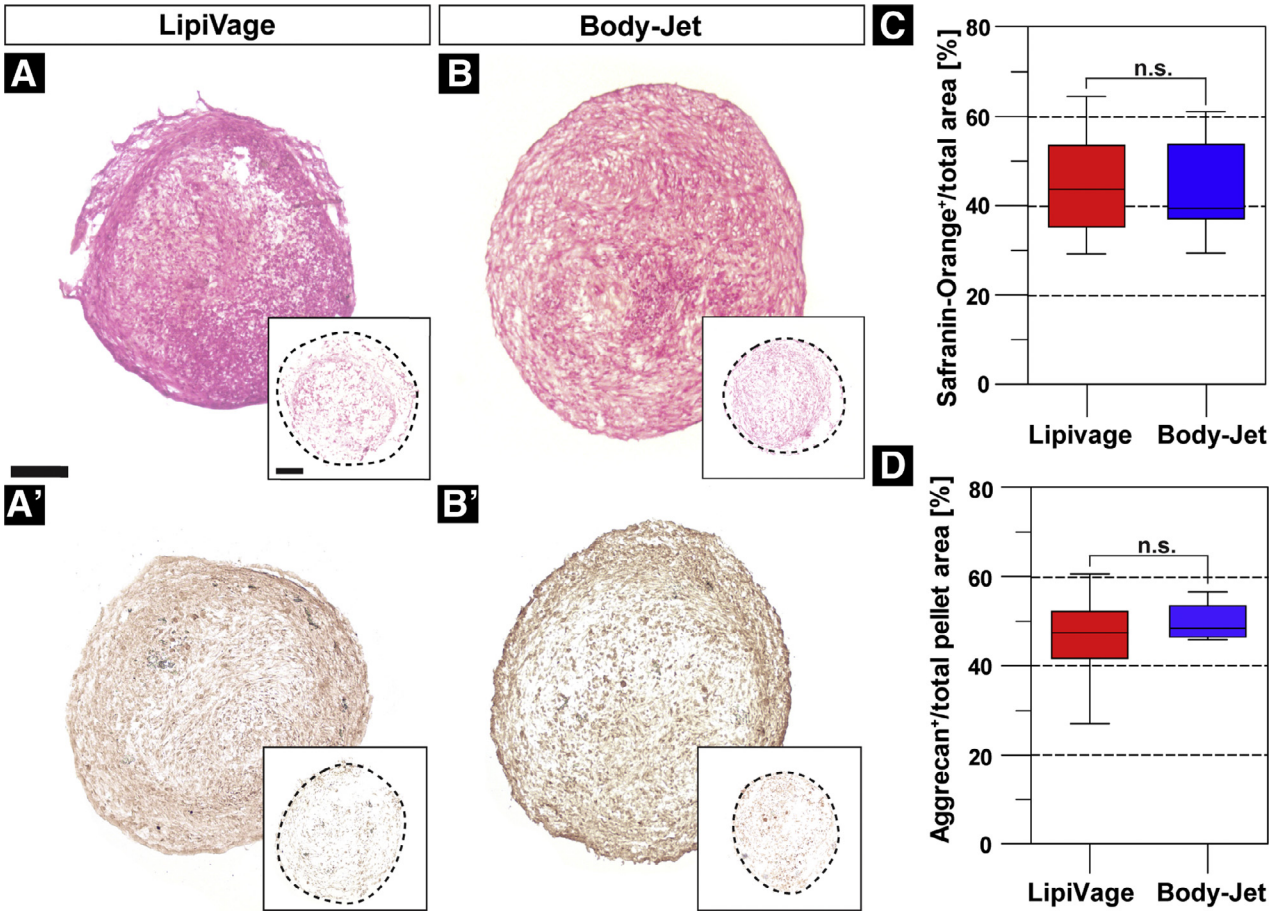

Figure 6 Deposition of proteoglycans in pellet culture indicates comparable chondrogenic differentiation of LipiVage- and Body-Jet-isolated ADSPCs. Extracellular matrix sulfated proteoglycan deposition was revealed by Safranin- Orange (A/B) and aggrecan staining (A′/B′) after 28 days in pellet culture. Unstimulated negative controls did not show deposition of proteoglycans (Fig.4A/A' and B/B', inserts). Quantitative analysis of the Safranin-Orange and aggrecan accumulation did not reveal a significant difference in the chondrogenic differentiation potential between the Body-Jet and LipiVage200-5 groups (C/D). Scale bar: 400 μm.

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Thus, we studied the differences between two techniques. The selected methods Body-Jet and LipiVage200-5 show great differences with regard to the fat-harvesting procedure. Nonetheless, both systems are used in everyday clinical practice for different indications[19,21].

Within the scope of our study, we evaluated cell proliferation by calculating the cumulative population doubling and the population doubling time during a period of 30 days. In addition, we assessed the number of colonies formed with the CFU assay and the cell metabolism activity with the WST-1 assay. We could show that ADSPCs isolated from fat tissue with either method displayed similar results for metabolic activity. However, ADSPCs from the Body-Jet group showed a significantly greater population doubling rate than ADSPCs in the LipiVage group.

Further studies regarding currently commercially available medical devices have shown similar results to ours[21,28]. A study by Bony et al. showed that ADSPCs derived from fat tissue, harvested with the Body-Jet system, display similar cell characteristics as those of ADSPCs derived from fat obtained through manual liposuction[22]. To the best of our knowledge, there currently is no comparable study that assesses cell properties of ADSPCs isolated with the LipiVage liposuction system. Our results provide evidence that ADSPCs from fat tissue, obtained with the Body-Jet and LipiVage system, feature a comparable metabolic capacity but a significantly different proliferation capacity. Regarding the functional properties of ADSPCs, we analyzed their potential to differentiate toward the adipogenic, osteogenic, and chondrogenic lineages. Our results could not show any significant differences between the two liposuction techniques. Previous studies from Yin et al. and from Bony et al. have shown an equivalent adipogenic and osteogenic differentiation potential for ADSPCs isolated from adipose tissue harvested with a water-jet-assisted liposuction system compared to that with the manual liposuction[21,22]. However, these studies did not examine the chondrogenic potential of isolated ADSPCs. Our findings verify a strong chondrogenic potential for ADSPCs obtained with both liposuction techniques. Altogether, the present study shows equivalent cell characteristics and functional properties for ADSPCs isolated with the two procedures, confirming that both liposuction techniques may be used to isolate functional ADSPCs. Furthermore, our findings are well in line with the studies available[3,21,22].

However, we emphasize that our data revealed a significantly higher cumPD and a tendency of higher adipogenic potential for cells isolated with the Body-Jet system. These findings might be explained through differently composed SVFs, containing heterogeneous subpopulations of stem and more committed progenitor cells, which were isolated through the two different liposuction techniques. A study by Bajek et al. demonstrated that ADSPCs obtained during manual and ultrasound-assisted liposuction show differences in antigen expression in 52 surface markers from the 242 studied[23]. We hypothesize that these different subpopulations of stem/progenitor cells might display different cell functions leading to the differences in cumPD rate and adipogenic differentiation potential.

Özsoy et al. revealed that the cannula diameter of liposuction devices affects the number of viable adipocytes. The study showed that the usage of a 4-mm-diameter aspiration cannula results in a greater number of viable adipocytes than utilization of a 2.5-mm-diameter cannula[29]. However, considering the following facts, greater cell viability might not necessarily lead to greater cell proliferation rates. During adipogenesis, pre-adipocytes undergo cell hyperplasia and hypertrophy to differentiate into adipocytes[30,31]. Due to the use of bigger cannulas, more committed progenitor cells might be isolated in higher amounts. These more committed progenitor cells in the isolated SVF might lead to a lower proliferation rate and a weaker adipogenic differentiation potential than the potentially more effective early-stage progenitor/stem cells. For liposuction with the LipiVage system aspiration cannulas with a diameter of 3–5 mm are used. In contrast, liposuctions with the Body-Jet system are performed with cannulas with a diameter of 3.5 or 3.8 mm. In practice, however, the diameter is smaller, as the cannula contains a water-jet tube, resulting in a diameter of approximately 2 mm. Furthermore, Hasanzadeh et al. showed in their study that chemical and mechanical stress plays a major role in the differentiation of ADSPCs toward other cell linages[32]. Kim et al. demonstrated in their study that shear stress leads to higher proliferation rates and stronger actin structures of ADSPCs[33]. These findings also might support the hypothesis that different cannula sizes have an impact on the characteristics of ADSPCs, as the different cannula diameters potentially lead to various shear stresses. Taken together, a bigger cannula diameter with less shear stress on cells might result in a greater number of viable cells. However, these cells might be in a greater number hypertrophic, more committed progenitor cells with a low proliferation potential. In contrast, shear stress in cannulas with a smaller diameter might lead to a lower number of viable hypertrophic cells but a higher number of smaller more, potent progenitor cells. Nevertheless, these assumptions should be studied in a follow-up study, in which for each liposuction technique, different cannula sizes are used and compared.

From a clinical point of view, it has been shown that the Body-Jet technique is associated with lower pain levels and ecchymiosis, indicating less trauma to nerves, tissue and blood vessels than those used in manual liposuction. Further advantages of the Body-Jet system over manual liposuction are the rapidity and large quantity of fat tissue collection[34]. These findings indicate that the Body-Jet system can ideally be used for extensive liposuctions, where a high quantity of adipose tissue needs to be harvested. The LipiVage is a closed system that combines tissue removal and filtering, as well as its transfer back to the patient in one setting. As the cannula may hold up to 200 ml of tissue at a time, this system is ideal for smaller procedures, which require a smooth detachment.

In addition, the financial aspect should be taken into consideration, as the LipiVage system represents a more cost-effective method than the Body-Jet system. The single use of the LipiVage system costs 328 Euro, whereas the costs for the Body-Jet are 371 Euro in Germany. However, the Body-Jet liposuction device itself has to be purchased for several thousands of Euros, whereas the LipiVage device is a disposable system and does not require any additional costs. This difference in the usage costs can lead to a more frequent use of the LipiVage system, even though the Body-Jet system might be the slightly better technique.

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In summary, our comparative analysis shows that the tested liposuction techniques LipiVage and Body-Jet can be seen as equally viable methods for the isolation of ADSPCs for further use in regenerative research and medicine. However, donor heterogeneity with regard to age and fat ratio may constitute the limitation of this study.

Conclusion

To date, the properties of ADSPCs harvested with different liposuction techniques have not been investigated sufficiently. The lack of knowledge may be one of the factors limiting the use of ADSPCs in clinical approaches. We show convincing evidence that the cell characteristics and the functional properties of ADSPCs isolated by different fat-harvesting methods are similar. Consequently, ADSPCs obtained with the Body-Jet and LipiVage liposuction technique should be equally considered for clinical use.

Declaration of Competing Interest

All authors declare no competing or financial interests.

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